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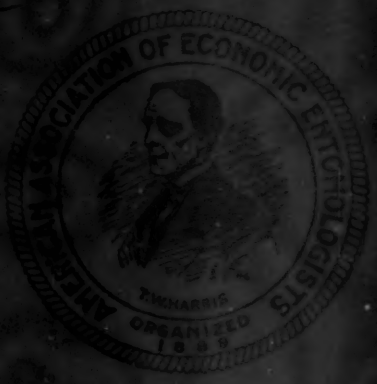

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A PROGRESS REPORT ON SOME INSECTICIDES USED AGAINST THE EUROPEAN CORN BORER

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ABSTRACT

This progress report offers some data relative to the reductions in the European corn borer (*Pyrausta nubilalis* Hubn.) populations resulting from the application of some common insecticides to corn.

Certain insecticides have been used on corn to determine their possible value in reducing populations of the European corn borer, *Pyrausta nubilalis* Hubn. and to obtain some information on the practicability of such treatments in reducing infestations and losses. The experiments have extended over a period of five years and have aimed at the testing of some of the insecticides in common use. During this period, notable differences have existed in the climatic conditions, in the growth conditions of corn, in the population levels of the treated areas and in the behavior of the borer. The characteristically spotted condition of the infestation and population in the fields used for treatment has also been a factor in producing variations in control or reduction figures. Hence, results have from year to year been inconsistent and variable in reference to some materials.

CLIMATIC CONDITIONS

The 1930 season, in particular, was abnormally hot and dry. These drought conditions have, in some instances, increased the larval reductions and injuries to corn resulting from the application of some materials which have not since produced equivalent results.

The rapid growth of the corn at the time the eggs are being laid and are hatching in the field has rendered it difficult, except by frequent application, to keep the plants covered with any material. Since a large part of the eggs are laid and a large part of the newly hatched larvae establish themselves on the new growth, it appears as though

the problem of supplying complete coverage could only be accomplished by frequent application. This was not so true during the 1930 season as the lack of rain during the period of treatment was conducive to good sticking. Also, the relatively slow rate of growth of the corn resulting from the drought conditions allowed for more complete coverage than was possible during the other seasons of study.

Population Levels

Average populations as determined in the untreated or check areas in the fields used for treatment have varied greatly during the five-year period. The lowest population occurred in 1930 when an average of 30 borers per 100 plants existed in the corn used for treatment and the highest population was an average of 520 larvae per 100 plants in the field used in 1928. The population in 1929 was 363 larvae per 100 plants, in 1931 an average of 219 borers per 100 plants and in 1932 an average of 218 borers per 100 plants occurred in the corn in these check areas.

Methods of Treatment

Each plot of corn has been given from one to four applications. The same general plan of timing applications has been used during the five years. When only one application was used, this was put on at or about the time the maximum number of eggs were hatching in the field or at approximately five days following maximum oviposition. When two applications were used, the application at the hatching peak was made and was followed by another in from five to seven days. When the corn received three treatments, an additional one was put on at approximately three days prior to the time when maximum oviposition was anticipated. In 1928 a fourth application was made just prior to the conclusion of egg laying.

Because of the abnormal trend of the 1932 egg deposition only two applications of any material were made. Maximum egg laying occurred on July 1 and the first application was made on July 5. Moth activity almost ceased following the maximum or peak of oviposition but the moths again became active and a second peak in egg laying occurred on July 9. The second application was made on July 11 and 12.

Spray applications were made in 1928 and 1929 with compressed air hand sprayers and during the remaining three years with a single cylinder spray pump operated by hand at a pressure of approximately 175 pounds. Dust applications were made with a bellows type hand

duster in 1928 and 1929 and with a rotary type hand duster during the remaining seasons.

Spray plots were approximately one-fortieth acre in extent and consisted of five rows sixty feet long. The dust plots were of the same dimensions in all years except 1931 when plots of one-tenth acre were used. The results presented here were obtained on a local strain of yellow dent corn. The larval reductions secured by these treatments were slightly greater than have resulted from equivalent applications of the same insecticides to sweet corn in the one instance in 1931 when both types of corn were given comparable treatment with a relatively few insecticides.

The number of plants dissected in each of the treated and check plots has varied with the population. The lowest number was 50 and the highest 100.

FLUOSILICATES.—Barium fluosilicate was used in 1930 at the rate of 4 pounds to 100 gallons of water. Very severe injury resulted from the first two applications and a contemplated third application was withheld. The characteristic fluorine bleaching was present on all parts of the plants touched by the spray and the premature death of those leaves receiving two applications resulted. The yield was greatly reduced. In the other trials with this material it was used at half of this strength (Table 1) and produced satisfactory larval re-

TABLE 1. LARVAL REDUCTIONS RESULTING FROM APPLICATIONS OF BARIUM FLUOSILICATE, CALCIUM FLUOSILICATE AND COMBINATIONS

Material	Concentration	Year	Time and No. of applications	No. of trials	Per cent larval reduction
Barium fluosilicate[1]....	2 lbs.—100 gals.	1931	July 2, 7, 13	3	85.6
Barium fluosilicate[1]....	2 lbs.—100 gals.	1932	July 5, 11	3	54.3
Barium fluosilicate[1]....	2 lbs.—100 gals.				
White summer oil[3].....	2 qts.—100 gals.	1932	July 5, 11	3	71.9
Barium fluosilicate[1]....	2 lbs.—100 gals.				
Fish oil.....	2 qts.—100 gals.	1932	July 5, 11	3	56.2
Barium fluosilicate[1]....	20 per cent				
Talc.....	80 per cent	1931	July 2, 7, 14	4	57.0
Barium fluosilicate[1]....	20 per cent				
Talc.....	76 per cent				
Neutral white oil.....	4 per cent	1931	July 2, 7, 14	4	65.4
Barium fluosilicate[1]....	20 per cent				
Talc.....	76 per cent				
Neutral white oil.....	4 per cent	1932	July 5, 11	3	60.6
Calcium fluosilicate[2]...	10 lbs.—100 gals.	1932	July 5, 11	3	73.7
Calcium fluosilicate[2]...	50 per cent				
Talc.....	50 per cent	1932	July 5, 11	3	55.62

[1]Proprietary compound: 80% barium fluosilicate, 20% inert material.
[2]Proprietary compound: 15% calcium fluosilicate, 85% inert material.
[3]Proprietary emulsion containing 65% actual oil; viscosity 80–85 sec., Saybolt at 100 degrees F. Used at the rate of 2 qts. actual oil per 100 gals.

ductions. At the rate of 2 pounds to 100 gallons some bleaching of the leaves has occurred where two and three applications have accumulated but yields have apparently not been depressed. This typical injury has been present in the dusted plots to a limited and much lesser extent and yield reductions, if present, have been small.

Calcium fluosilicate has shown less tendency to injure the plants than barium in the one year in which it has been tested. It appears to be equally toxic to the borers and is the most promising material used to date.

In preliminary experiments with sodium fluosilicate severe injuries have resulted from its application in dust form at the rate of 20 per cent of the fluosilicate and 80 per cent talc.

ARSENICALS.—Acid lead arsenate has been one of the best materials used when considered from the point of view of injury to the plants and has produced no reductions in yield. The rate of kill has not been high when used by itself (Table 2) but when combined with oil emulsions quite satisfactory larval reductions have resulted from three applications of the combination. In 1931, 62.8 per cent of the borers were apparently killed with the oil and lead combinations as compared to 49.7 per cent in the case of the same oil used at the same concentration but lacking the lead arsenate. When combined with summer oil emulsion three and two applications used in 1931 and 1932 have not reduced yields.

TABLE 2. LARVAL REDUCTIONS RESULTING FROM THE USE OF ARSENICALS AND ARSENICAL COMBINATIONS

Material	Concentration	Year	Time and No. of application	No. of trials	Per cent larval reduction
Acid lead arsenate.....	4 lbs.—100 gals.	1931	July 2, 7, 13	3	47.8
Acid lead arsenate.....	4 lbs.—100 gals.				
Summer oil emulsion[1]..	1 —100	1931	July 2, 7, 13	3	62.8
Acid lead arsenate.....	4 lbs.—100 gals.				
Summer oil emulsion[2]..	1 —100	1932	July 5, 11	3	61.4
Acid lead arsenate.....	20 per cent				
Hydrated lime.....	76 per cent				
Neutral white oil.....	4 per cent	1931	July 2, 7, 13	4	46.6
Acid lead arsenate.....	20 per cent				
Talc.....	80 per cent	1930	July 2, 8, 17	2	42.8

[1]Proprietary emulsion; 65% oil.
[2]Proprietary emulsion; 65% oil used at rate of 1% actual oil.

Calcium arsenate has not been as satisfactory as lead at the strength at which it has been used. In spray form, 4 pounds of the calcium arsenate to 100 gallons of water produced dead areas in the leaves and desiccation and premature death of the tissues at the margins of the leaves.

MECHANICAL BARRIERS.—The use of talc and hydrated lime as mechanical barriers to newly hatched larvae and as deterrents to egg laying have not given satisfactory results. Oviposition records have indicated that hydrated lime did not prohibit egg laying to any marked extent. An average of 15.56 eggs per plant were taken on the plots dusted four times in 1928 with hydrated lime while an average of 20.16 eggs per plant were taken in the adjacent check areas. Larval reductions due to treatments with the talc and hydrated lime in spray and dust forms have all been comparatively small. In the single instance of an excessive dosage of talc (Table 3) applied in suspension

TABLE 3. LARVAL REDUCTIONS RESULTING FROM THE USE OF TALC AND HYDRATED LIME AS MECHANICAL BARRIERS

Material	Concentration	Year	Time and No. of applications	No. of trials	Per cent larval reduction
Hydrated lime.....	Pure	1928	July 7, 12, 17, 27	2	23.6
Hydrated lime.....	10 lbs.—100 gals.	1930	July 2, 8, 14	2	33.0
Talc.....	Pure	1930	July 2, 8, 14	2	34.2
Talc.....	10 lbs.—100 gals.	1930	July 2, 8, 14	2	21.0
Talc.....	1 lb.—1 gal.	1930	July 3, 9, 17	1	53.5

in water severe injury occurred to the corn in the form of desiccation and retarded growth. The remaining plots treated with lime and talc were uninjured.

TABLE 4. LARVAL REDUCTIONS RESULTING FROM APPLICATIONS OF PYRETHRUM AND COMBINATIONS CONTAINING PYRETHRUM

Material	Concentration	Year	Time and No. of applications	No. of trials	Per cent larval reduction
Pyrethrum soap[1].....	1–800	1930	July 2, 9, 17	1	42.7
Pyrethrum soap[1].....	1–800	1931	July 2, 7, 13	3	48.6
Pyrethrum soap[1].....	1–800				
Summer oil emulsion[3]..	1–100	1931	July 2, 7, 13	3	65.4
Pyrethrum soap[1].....	1–800				
Summer oil emulsion[3]..	1–100	1929	July 4, 11, 16	3	72.0
Pyrethrum soap[1].....	1–800				
Summer oil emulsion[3]..	1–100	1929	July 11, 16	1	54.4
Pyrethrum soap[1].....	1–800				
Summer oil emulsion[3]..	1–100	1929	July 11	1	54.0
Pyrethrum soap[1].....	1–800				
Summer oil emulsion[3]..	1–100	1929	July 4, 11, 16	3	58.6
Pyrethrum soap[1].....	1–800				
Summer oil emulsion[2]..	1–100	1928	July 7, 12, 17, 27,	2	54.3
Pyrethrum soap[1].....	1–800				
Summer oil emulsion[3]..	1–100	1928	July 7, 12, 17, 27	2	62.9
Pyrethrum soap[1].....	1–400	1932	July 5, 11	3	37.8
Pyrethrum soap[1].....	1–400				
Rotenone.....	1–40000	1932	July 5, 11	3	53.6

[1]Proprietary compound containing 1.82 grams of pyrethrum per 100 cc.
[2]Proprietary emulsion containing 65% actual oil; viscosity 80–85 sec., Saybolt at 100 degrees F.
[3]Proprietary emulsion containing 65% actual oil; viscosity 150 sec., Saybolt at 100 degrees F.

PYRETHRUM.—Pyrethrum has not produced adequate larval reductions when used in soap form when two and three applications have been given. When combined with oil it appears to have slightly increased the value of the emulsions in reducing populations.

There has been no evidence of external injury or decreased yield from the use of pyrethrum and the pyrethrum and oil combinations have been found as satisfactory as the oil emulsions lacking this ingredient from the point of view of plant tolerance.

OIL SPRAYS.—Oil sprays have been used by themselves or as vehicles for the application of other materials for the past five years and have given quite marked larval reductions. The number of applications that can be applied without producing injury and the low concentrations that can be used because of the same reason have distinctly limited the kill that could be secured in these experiments. A summer oil having a viscosity of 80–85 sec., Saybolt at 100 degrees F., has been the most satisfactory of any of those used. The heavier and less volatile oils have been found dangerous to use because of the accumulation of the oil on the lower parts of the plants when more than one application has been applied. This accumulation has re-

TABLE 5. LARVAL REDUCTIONS RESULTING FROM SPRAY APPLICATIONS OF OIL

Material	Concentration	Year	Time and No. of application	No. of trials	Per cent larval reduction
Neutral white oil[1]	1–100	1929	July 4, 11, 16	3	75.6
Neutral white oil[1]	1–100	1929	July 11, 16	1	62.1
Neutral white oil[1]	1–100	1929	July 11	1	54.2
Neutral white oil[2]	1–100	1929	July 4, 11, 16	3	75.8
Neutral white oil[2]	1–100	1929	July 11, 16	1	60.4
Neutral white oil[2]	1–100	1929	July 4	1	56.7
Neutral white oil[3]	1–100	1929	July 4, 11, 16	3	51.6
Neutral white oil[4]	1–100	1929	July 4, 11, 16	3	58.1
Summer oil emulsion[5]	1–100	1929	July 4, 11, 16	3	60.4
Summer oil emulsion[5]	1–100	1929	July 11, 16	1	57.6
Summer oil emulsion[5]	1–100	1929	July 11	1	43.1
Kerosene	2–100	1929	July 4, 11, 16	3	52.0
Kerosene	1–100	1929	July 4, 11, 16	3	50.6
Summer oil emulsion[6]	1–100	1931	July 2, 7, 13	3	49.7
Summer oil emulsion[6]	2–100	1932	July 5, 11	3	78.8
Neutral white oil	1–100	1930	July 2, 8, 17	3	68.0
Pine oil	1–100	1930	July 2, 8, 17	3	78.1
Linseed oil	1–100	1929	July 4, 11, 16	3	72.0
Cottonseed oil	1–100	1929	July 4, 11, 16	3	50.6

[1]Viscosity 80–85 sec., Saybolt at 100 degrees F.
[2]Viscosity 125 sec., Saybolt at 100 degrees F.
[3]Viscosity 180 sec., Saybolt at 100 degrees F.
[4]Viscosity 225 sec., Saybolt at 100 degrees F.
[5]Proprietary emulsion 85% oil.
[6]Proprietary emulsion 65% oil.
[7]Proprietary emulsion 65% oil; 2% actual oil used.

sulted in the premature death of the lower leaves and yield reductions have been evident. Although the greater part of the kill seems to have been produced by the one application put on at maximum hatching time, (Table 5) additional applications appear to be necessary in order to insure a reasonable degree of larval reduction. Emulsions containing 1 per cent actual oil have appeared to be the strongest concentration that could be used safely for three applications with any of the particular oils tested. Two per cent emulsions have been injurious to the plants when applied twice.

DERRIS.—Derris has been used with oil emulsions at a concentration of 1–800 and 1–1600 of a proprietary compound (Table 6). In these combinations it has been only slightly better than the emulsions lacking derris from the point of view of larval reduction. It has appeared to increase the injury produced by the emulsions but this increased injury has not been evident in yield reductions.

TABLE 6. LARVAL REDUCTIONS RESULTING FROM SPRAY APPLICATIONS OF DERRIS AND DERRIS-OIL COMBINATIONS

Material	Concentration	Year	No. and time of application	No. of trials	Per cent larval reduction
Derris[2]	1–1600				
Summer oil emulsion[1]	1–100	1928	July 7, 12, 17, 27	2	63.8
Derris[2]	1–1600				
Summer oil emulsion[1]	1–100	1929	July 4, 11, 16	3	64.1
Derris[2]	1–1600				
Summer oil emulsion	1–100	1929	July 11, 16	1	52.2
Derris[2]	1–1600				
Summer oil emulsion	1–100	1929	July 11	1	34.9
Derris[2]	1–800				
Neutral white oil	1–100	1930	July 2, 8, 17	1	67.2
Derris[2]	1–800				
Summer oil emulsion[1]	1–100	1931	July 2, 7, 13	3	55.2

[1]Proprietary emulsion 65% oil 80–85 sec., Saybolt at 100 degrees F.
[2]Proprietary compound; derris resin 5%, fatty acid 50%; inert matter 45%.

NICOTINE.—Nicotine sulphate has given variable results from year to year, depending probably on the climatic conditions at the time of application. Preliminary tests of this material in combination with an oxidized oil and applied during extreme heat in 1930 appeared to produce a high rate of kill. However, these results have not been duplicated in 1931 and 1932 and nicotine cannot be considered a satisfactory insecticide for corn borer by itself. It may have increased slightly the efficiency of oil emulsions. Free nicotine and tannic acid have given better results than nicotine sulphate or nicotine sulphate and oxidized oil in the one year in which they have been studied comparatively.

TABLE 7. LARVAL REDUCTIONS RESULTING FROM APPLICATIONS OF NICOTINE AND COMBINATIONS AS SPRAYS

Material	Concentration	Year	No. and time of application	No. of trials	Per cent larval reduction
Nicotine sulphate (40%)	1–800				
Potash fish oil soap	1–400	1931	July 2, 7, 13	3	36.0
Nicotine sulphate (40%)	1–400				
Potash fish oil soap	1–400	1932	July 5, 11	3	8.9
Free nicotine (50%)	1–400				
Tannic acid	1–200	1932	July 5, 11	3	56.7
Nicotine sulphate (40%)	1–400				
Oxidized oil[1]	1–200	1932	July 5, 11	3	46.6
Nicotine sulphate (40%)	1–800				
Summer oil emulsion[2]	1–100	1931	July 2, 7, 13	3	63.3

[1]Proprietary compound; oxidized petroleum hydrocarbons 80%; inert materials 20%.

[2]Proprietary emulsion containing 65% oil; 1% actual oil used.

DISCUSSION.—Such attempts as have been made to reduce corn borer infestation and population by insecticidal applications have for the most part been unsatisfactory. The corn used has been making a rapid growth and has been easily injured at the time that applications of the poisons have been made and the margin of safety between materials capable of reducing populations and producing injuries to the plants has seemed extremely low. Insecticides applied as dusts have been less effective in reducing populations than the same insecticides when applied in spray form. Hydrated lime and talc have been unsatisfactory when used as mechanical barriers to young larvae. Such oils as have been used have required three applications to give satisfactory larval reductions at safe strengths. Nicotine and pyrethrum have not given satisfactory results when used by themselves and have along with derris, added little if anything to the oil emulsions from the point of view of reducing infestations. Arsenate of lead has produced too low a larval reduction when used by itself to seem of practical value but when used with an oil has given reasonable kills with three applications. Barium fluosilicate by itself and in combination with dilute oil emulsions has given marked larval reductions but these reductions have been accompanied by some injury. Calcium fluosilicate, although tested only during one year, appears at this time to be the most satisfactory insecticide for use against the European corn borer that has been included in these studies.

SOME ECOLOGICAL ASPECTS OF EUROPEAN CORN BORER ABUNDANCE

By L. L. HUBER and J. B. POLIVKA

It is the purpose of this paper to review briefly the behavior of the European corn borer in the Lake Erie region, specifically in Ontario, Canada, and in Ohio. Published records have indicated the differences in population, not only from year to year but also in various types of habitats. In many instances, certain conditions of weather or soil, or both, have been cited as probable or specific controlling factors. For example, a period of abnormal temperature during moth flight may reduce egg deposition. It should be remembered, however, that the significance of such a factor is only relative. Furthermore, the study of certain environmental factors in combination still falls short of the requirements of a major biological problem. It seems, therefore, that the ultimate interpretation of the effects that factors produce on the behavior of the borer will have to be expressed in terms of the physiology of the organism as a whole. This is to say, that it would be desirable to obtain and use some measurement which represents an integration of the total environment. The yield of corn in the area where the borer is present approaches such a desideratum.

The corn yield data used herein represent the entire State of Ohio and the entire Province of Ontario, whereas the estimates of corn borer abundance represent only a small portion of these two regions. While it is desirable to correlate corn borer behavior with yields in the particular areas where the borer is abundant, it remains true that the trends of yields in the areas where the insect is relatively abundant are the same as for the regions as a whole. Such deviations as exist are not considered important for the present purpose. In other words, to the extent that corn yields over these entire areas represent the general trend in the areas where the borer has been present for some time and to the extent that yields represent an integrated measurement of the environment, particularly during the growing season, it is possible to use them to express certain ecological relationships.

Published records[1] indicate that in Ontario there were only 2 poor corn years from 1909 to 1923, inclusive (Fig. 54). Furthermore, from 1909 to 1915, inclusive, the yields were considerably above normal

[1]Ontario Department of Agriculture. Statistics and Publications Branch, Crop Bulletins, 1909–1931.

for 7 years in succession, and from 1918 to 1923, inclusive, they were normal or above for 6 successive years. On the contrary, from 1924 to 1931, inclusive, there was only one year in which production was

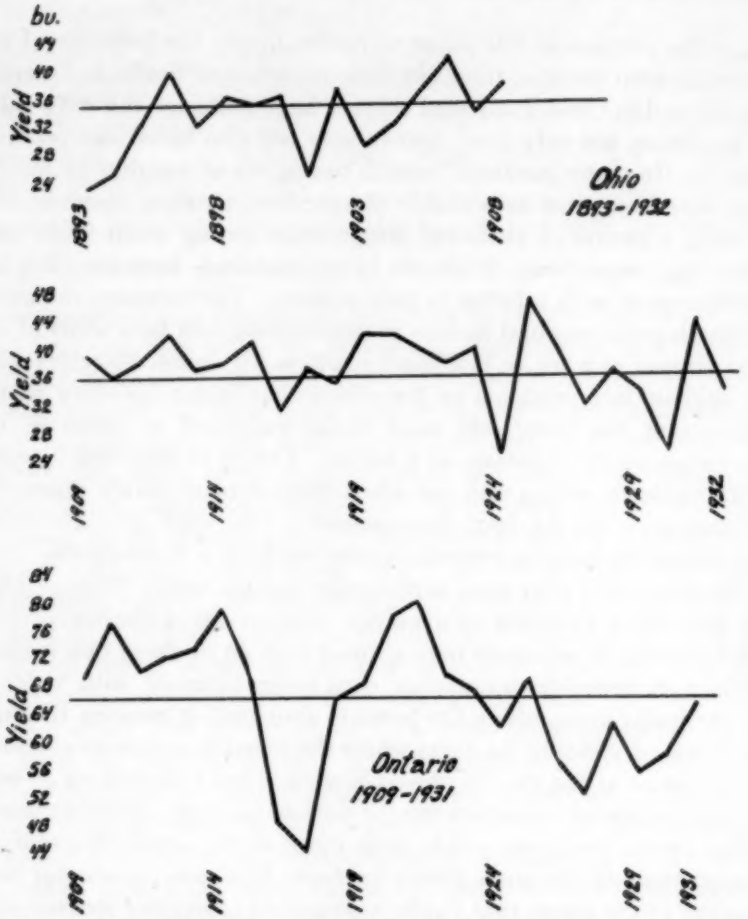


Fig. 54.—Showing yield of corn per acre in Ohio and in Ontario, Canada, from 1893–1932, and 1909–1931, respectively.

above normal. It should be pointed out, however, that the low yield of 1926 was due, in part, to corn borer damage; to a lesser extent this is perhaps true for the few years immediately preceding 1926. In Ohio, the expected yield of corn is based on records for 40 years. An examination of these records[3] shows that from 1905 to 1926, in-

[3]United States Department of Agriculture, Year Book, 1893–1932.

clusive, a period of 22 years, the yields were above the expected for 17 years, that during this time no poor corn years occurred in succession, and that prior to 1905 and since 1926 the tendency of production has been subnormal. In the entire 40-year period, 2 normal or above corn years have appeared in succession 15 times, whereas 2 subnormal years have appeared only four times in succession. Without going into further detail, it should be apparent that insofar as these statements suggest the expectations of the future they are of considerable importance. This is particularly true when the causal and concomitant relationships of borer behavior and corn development are remembered.

Records show that from the time the borer was discovered in Ontario in 1920 to the time when heavy losses occurred in 1926, the population increased steadily. On the contrary, from 1927 to the present there has been a continued tendency toward maintaining a rather low population. These periods of high and low trends have corresponded to the periods of above and below normal corn production, respectively. Similar records in Ohio suggest that up to and including 1926 the borer increased quite rapidly. In 1927, there was a tendency to maintain the *status quo*, whereas in 1928, a better than average corn year, the population again reached a new level. When corn production fell below normal in 1929, the borer population showed no extraordinary upward trend but rather a tendency toward maintaining the 1928 level. However, when yields continued downward in 1930, corn borer population suffered a severe reduction. On the other hand, with the occurrence of a good corn year in 1931, the insect tended to reach its former level. In 1932, with a poorer than average condition of corn through the growing season, the borer again showed only a negligible tendency to increase.

On the basis of these facts, it appears that certain general, though tentative, conclusions may be drawn: (1) That ecological conditions, on the whole and especially since 1926, have been unfavorable to the borer in Ohio; only in isolated areas or on ecological islands have high populations been persistent. (2) That the corn borer, unless control is effected, probably will cause serious losses in wide areas when conditions are normal or above for a period of 2 or more years in succession, although this is not to say that losses will not occur the first year, particularly if the overwintering population is sufficiently high. (3) That when an unfavorable year follows a favorable one the borer population is likely to manifest a tendency to maintain the

status quo; but, if the second and succeeding years are also below normal, the population probably will show a significant decrease. This, of course, does not preclude the possibility that an extremely high population accompanying a period of favorable years may cause damage the following year even though ecological conditions are subnormal.

SUGAR CANE BORER CONTROL BY *TRICHOGRAMMA* COLONIZATION IN LOUISIANA IN 1932

By W. E. Hinds, B. A. Osterberger and A. L. Dugas, *Louisiana Experiment Station*

Abstract

This paper reports experimental work with colonization of *Trichogramma minutum* for control of the sugarcane borer (*Diatraea saccharalis*) in corn and cane fields in Louisiana. It is shown that colonization increases very abruptly the parasitism percentage in colonized fields of cane and corn and that the parasites spread quite promptly into adjacent fields. The average percentage of borer eggs destroyed in colonized and adjacent fields was about 28% greater than in comparable check areas for the latter portion of the season. This higher destruction of borer eggs resulted in a decided decrease in the proportion of stalks bored, joints bored and moth population produced per acre in millable cane. About 6000 millable stalks per acre were saved apparently by parasite colonization. By decreasing the borer attack on cane there was found to have been an average saving of from 21 to 25 pounds of sugar per ton of cane in an average of all protected areas. The cost of colonization work averaged less than $1.00 per acre.

Several previous reports upon this project have appeared in the Journal of Economic Entomology. The subject is continued because it appears that, contrary to the expectations and opinions of various specialists in biological control of insects, the work of establishing early season colonies of *Trichogramma* in and adjacent to cane fields is actually producing beneficial results in Louisiana and further progress has been made in the measurement of the benefits therefrom.

It is impossible to present more than a summary survey of the mass of data which has been accumulated on this subject. Many phases of the work can not be mentioned and the discussion must necessarily be too brief to cover the subject adequately or perhaps convincingly for those outside of the sugarcane belt. In this work we shall speak of borer damage alone although we know that in addition to the

damage done by the sugarcane borer there is a certain measure of damage occurring frequently also due to fungus diseases which in most cases secure their entrance primarily through the lesions caused by the cane borer larvae.

The general plan for the work for 1932 followed very closely that of 1931, except that somewhat smaller numbers of parasites were released in the colonized areas, averaging about 6000 per acre this season, and practically only one release was made for the season. The releases were made principally at the time that eggs were being laid for second or third generations. Many colonies were placed in fields of heavily borer infested corn closely adjacent to cane fields and check areas of both corn and cane were chosen. The cane checks were similarly exposed to borers coming from corn but with no parasitization of borer eggs except that occurring naturally. In every case the check areas were carefully selected to be as fully comparable as possible with the colonized and adjacent areas as an average, the latter two groups being considered together as "protected" areas. The initial borer infestation in June was higher in corn than in cane areas but varied little in the average of all corn or cane areas included in each group of "colonized," "adjacent" and "checks".

Borer egg collections were made in all test areas before any colonization and every three weeks thereafter until September 10. A definite time unit for egg collection in each area was used so that to some degree the abundance of borer egg batches might be compared. There is known to be a very considerable variation in the susceptibility of different varieties of sugarcane to attack by the sugarcane borer. Therefore comparisons were made only between fields of the same variety and planting date, or age of cane, and with previous cropping history uniform in each case. In a number of cases deliberate selection was made of locations which we had watched closely for several seasons and had known, therefore, that these were regularly very heavy infested areas where the damage to cane had been exceedingly heavy for several seasons past. Furthermore the borer population known to occur in these areas early in the spring of 1932 was exceptionally high. In these cases test comparisons could be made between colonizations at one side of a long stretch of cane consisting of several cuts, with checks at the opposite side of the stretch but where the exposure to borer infestation was similar. The results found at the end of the season in several such instances are particularly striking and convincing when considered in detail and with full knowledge

of the situation in each case. Rather than to depend upon a few such striking instances, we prefer to base our conclusions primarily upon the accumulated mass of data secured from a large number of fields representing a wide range in varieties of cane and in plantation practice. We believe that this basis indicates most surely what the average planter may reasonably expect where colonization work is done properly.

Also this season we have been able to make some records on quite a large series of fields where the work was done by county agents and plantation men rather than by members of the Experiment Station staff. In these cases where the work was done according to our instructions and at the proper time their results in the increase in parasitism, reduction in borer infestation and increase in yield and in sugar content of cane in colonized areas as compared with their own checks, have been practically parallel with those obtained in our own series of experiments.

PROGRESS OF PARASITISM IN "COLONIZED," "ADJACENT" AND "CHECK" AREAS, IN 1932. Altogether we have examined under microscopes more than 400,000 borer eggs during the season to determine the progress of borer infestation and *Trichogramma* parasitism in various areas.

The first series of colonizations was made in South Louisiana June 13–17 and included 20 fields of corn and 8 of cane at that time. The primary purpose in colonizing in these fields of corn was to develop as rapidly as possible a large local center for the development of *Trichogramma* from which the wasps might spread later into nearby fields of cane. We shall consider first the progress of parasitism in two groups of corn fields. In these the borer infestation and natural parasitism were, on the average, very similar before the time of colonization in one group.

TABLE 1. PROGRESS IN *Trichogramma* PARASITISM IN COLONIZED AND CHECK FIELDS OF EARLY CORN, 1932

(The percentages given are *weighted* averages)

No. of fields averaged	Test	Weighed average % Coll. 6/13–17	Coll. 7/1–9	Coll. 7/25–30
8	Check	17.4	36.4	53.5
11	Colonized	16.3	72.7	82.8

In the check corn fields the natural parasitism was slightly higher at the start than in the colonized. During the next six weeks natural parasitism in check areas increased three fold, while in the colonized

areas, with the addition of about 6000 parasites per acre there was an increase to five fold.

Naturally as the corn fields matured at about the latter part of July or early in August, both borer moths and parasites spread from

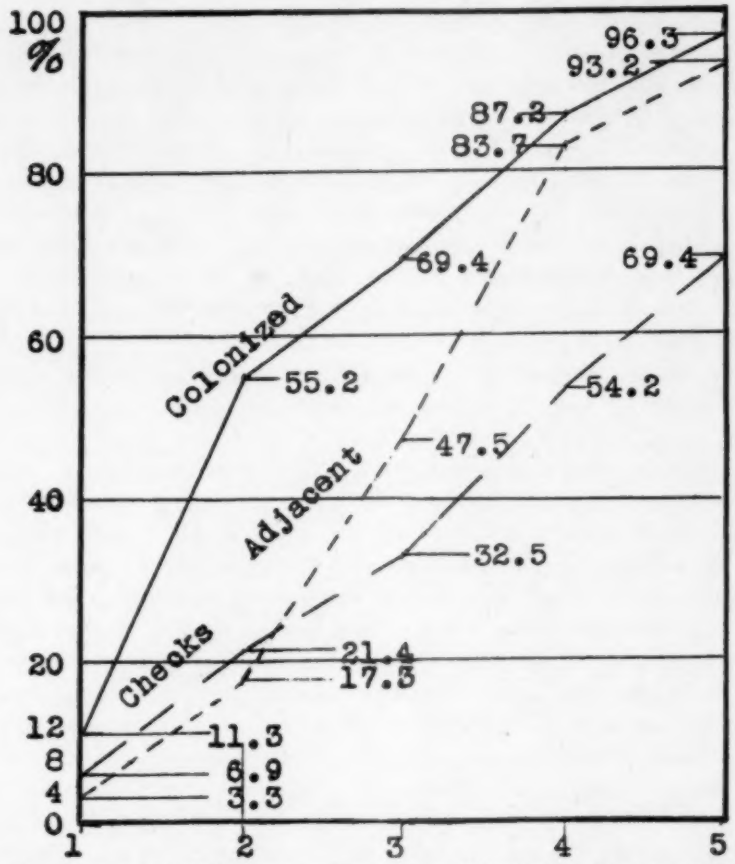


Fig. 55.—Progress of Trichogramma Parasitism, Colonized, Adjacent and Check Fields South La., Median collection dates: 1) June 15; 2) July 5; 3) July 28; 4) August 27; 5) Sept. 8, 1932.

these areas for a very considerable distance. The colonized corn fields must necessarily be dropped from consideration thereafter but the beneficial effects of colonizing these corn areas are shown strikingly in the very rapid increase of parasitism and the very highly effective control of the borer shown in the fields of cane adjacent to the colonized corn. (See graph, Fig. 55.)

Under average conditions of natural parasitism, cane growers well know that there is very grave danger of serious damage to cane grown closely adjacent to fields of early maturing corn. It is quite contrary to usual experience to have such adjacent cane fields less damaged by borer at the end of the season than similar fields grown at a distance from the corn areas.

The late season establishment of *Trichogramma* in many cane fields was shown by observations made at Plaquemine between July 26 and August 9. There on 8 plantations, in an examination of some 24 fields of cane, no parasitism whatever was found in 6 fields although borer eggs were abundant in some of them. Fourteen showed a parasitism of less than 20% with an average of 5.8%. The maximum found in one of these 24 naturally parasitized fields was 69%, while it happens that in an *average* of 22 colonized fields of cane in South Louisiana at the same period 69.4% of borer eggs had been parasitized. It would appear that the chances were at least 20 to 1 in favor of the parasitism in colonized areas reaching as high as 69% by the first of August, as compared with parasitism naturally developed.

In order to present a summary view of this mass of data as briefly as possible we have placed it in the form of a graph which appears herewith.

The progress of parasitism through the season is only one of several indices by which we measure the benefits of colonization work. From an examination of the graph it is quite clearly shown that in colonized areas there is a very rapid increase of parasitism during the first few weeks after the colony is established. The development in the check areas which at the middle of June were intermediate in parasitism between the colonized and adjacent fields, continues steadily and in nearly a straight line through the season to an average maximum of 69.4%. In the "adjacent" fields with only half the parasitism occurring in the checks at the beginning of the examinations, the development is parallel with that in the checks for the first few weeks and then as parasites spread from the early parasitized colonized areas into the "adjacent" fields the rate of increase in the "adjacent" fields rises very rapidly indeed until it approaches closely the percentage occurring in the colonized areas. The development in the check areas never overtook that in colonized and adjacent areas even in a comparison of individual field records, although by mid-season the infestation by borers in many of the check fields exceeded that in

any of the colonized or adjacent fields. A close study of individual field records shows clearly that the abundance of host eggs is not the only factor that governs the development of parasitism in any particular field. There is also a factor of the time at which the parasitism starts. When this start is late two generations of borers may have occurred and a great deal of damage may have been done to the cane which cannot be wiped out by late season high parasitism of borer eggs. *Trichogramma* does not develop spontaneously any more than does *Diatraea*. There is strong evidence that *Trichogramma* does not survive the winter in many cane fields and they may not reach all fields by their natural spread until after two or three generations of borers have developed and injury to the cane is already severe. We believe that *Trichogramma* control of *Diatraea* to be really effective must start early in the season, at least as early as borer infestation becomes moderately abundant, and this host condition may occur at the beginning of second, third and sometimes even as late as the fourth generation of borers.

Trichogramma Colonization Effects Upon Stalk Infestation and Moth Population Produced in Millable Cane, 1932. In securing these correlations all examinations were made by the same group of workers under the supervision of one man so that there was uniformity as to methods and personal equations throughout. The stand of cane per acre was determined on the basis of averaging the figures found at four representative locations situated some distance in from the ends and edges of each cut. In these locations also, 100 stalks were stripped and thoroughly examined for any signs of borer and those showing one or more borer burrows per stalk were classed as "bored." The emergence holes are conspicuous and were recorded for each group of stalks examined. On the basis of "stand" and ratio of emergence holes per 100 stalks, the moth population per acre in millable cane was determined.

Trichogramma Colonization Effects on Borer Egg Parasitization, Percentage of Stalks, Number of Borer Emergence Holes and Moth Population per Acre, 1932

Table 2. Progress of *Trichogramma* Parasitism 1932

Test group and No. fields	6/13–6/17	7/1–7/9	7/25–7/30	8/15–8/24	9/6–9/10
(A) 12 Col'd.....	5.7	36.8	64.3	87.2	96.4
(B) 18 Adj.....	3.1	14.4	47.5	83.7	93.2
(C) 21 Check.....	1.8	9.4	23.7	58.0	69.3

TABLE 3. BORER INFESTATION IN MILLABLE STALKS AND MOTH POPULATION PER ACRE, 1932

	Stalk Infestation		Moth population in mill cane		
Number examined	With 1 or more burrows %	Joints bored %	Emergence holes number	Average No. stalks per 1 emergence hole	Moths per A. average number
(A) 1200.....	64.0	13.5	173	7.0	3,422
(B) 1800.....	59.1	12.3	146	12.3	2,164
(C) 2100.....	93.0	31.8	793	2.6	6,057

From the data in Tables 2 and 3 it appears that "protected" areas (colonized and adjacent taken together) show the destruction of borer eggs to average fully one-third higher than in checks and that as a consequence there follows a reduction averaging about 33% in the percentage of stalks bored and averaging 60% in the percentage of joints bored. Furthermore the total moth population produced in millable cane through the season was only 46.1% of that in checks. These results are closely consistent with those found in 1931.

Trichogramma COLONIZATION EFFECTS UPON PROPORTIONS OF MILLABLE AND UNMILLABLE CANE. In the same fields a further study was made to determine the average stands of millable and unmillable stalks per acre. This was done by examining larger plats at four representative sections of each field and averaging the results for that area. Row-feet measurements were taken also and the proportion of unmillable stalks killed by borers was determined. All of these examinations were made by one man following uniform methods.

TABLE 4. BORER CONTROL MEASURED BY MILLABLE AND UNMILLABLE CANE—1932

Type and number fields	Number stalks examined	Original stand shoots per A	At harvest		Unmillable Killed by borer		Millable canes saved by colonization. Av. Number per acre
			Millable number	Unmillable number	No.	%	
31 Protected	12,400	34,880	25,288	9,592	7,499	78.2	6,000
28 Checks...	11,200	35,720	19,289	16,431	12,859	78.3	

In comparing these two sets of areas it is very striking that, while the original stand of sprouts was practically equal, the borers destroyed many more shoots in the check areas than in the protected areas. The difference amounted to 6,000 stalks per acre and this factor alone amounts to 25% of the yield in millable stalks secured on the average of all protected areas. We believe that this is the first time that a direct study of borer damage in the form of unmillable cane has been made in Louisiana. The conclusion as to loss from borer infestation in this form is supported also by field weight records on many plantations.

TABLE 5. *Trichogramma* COLONIZATION EFFECTS UPON PERCENTAGE OF STALKS BORED,[1] JOINTS BORED AND SUGAR PER TON OF CANE, 1932

Protected					Checks				
Variety of cane	Number of fields averaged	Percentage Stalks bored	Percentage Joints bored	Sugar per ton of cane aver. lbs.	Sugar per ton of cane aver. lbs.	Percentage Joints bored	Percentage Stalks bored	Number of fields averaged	Variety of cane
213 St.	5	73.3	15.3	178.90	155.71	30.4	95.0	5	213 St.
213 St.	2	61.5	13.6	151.51	141.56	41.2	99.0	2	213 St.
213 St. & Pl.	5	76.2	17.5	187.57	152.68	37.8	95.5	4	213 St. & Pl.
213 St. & Pl.	2	90.5	10.9	198.78	173.21	42.0	100.0	2	213 St. & Pl.
Total and average 213	14	75.1	15.4	180.94	155.11	36.4	96.5	13	213 total & aver.
(Average increase 25.83 lbs. per ton with POJ 213)									
36-M	2	34.5	5.7	143.19	126.51	29.7	78.0	2	36-M
36-M	1	16.0	3.6	201.06	180.78	28.1	97.0	1	36-M
Total and average 36-M	3	28.3	5.1	162.48	144.60	28.8	84.3	3	36-M total & aver.
(Average increase 17.88 lbs. per ton with POJ 36-M)									
807	2	48.5	8.8	155.94	131.88	27.33	98.0	1	807
807	1	41.0	7.0	170.53[2]	180.13[2]	26.8	90.0	1	807 (McC.)
807	1	75.0	10.9	195.33	176.71	19.8	89.0	1	807
Total and average 807	4	53.2	9.2	169.43	162.91	24.5	92.3	3	807 total & aver.
(Average increase 6.52 lbs. per ton with 807)									
234 Pl. total	1	71.0	13.9	210.00	175.96	31.9	94.0	1	234 Pl. total
(Average increase 34.04 lbs. per ton with 234)									
Co. 281 total	1	66.0	15.7	185.65[2]	189.89[2]	36.8	94.0	1	281 total
Composite: All protect.	23	64.6	13.7	178.0	157.08	33.1	89.4	21	Composite: all checks
(Composite average increase 20.92 lbs. per ton for all varieties)									

[1]Stalks are classed as "bored" if they show one or more borer burrows of any size. Many of these may be small or shallow burrows and cause no measurable injury to the stalk as a whole. The same is true for "joints bored."

[2]These two sets of fields (807 and 281) were grown on the same plantation. Being the only comparisons of 1932 that were *apparently* "out of line" with the general trend, a special investigation was made to find the explanation. It was then learned that a few years ago Bayou Teche mud had been pumped onto both "adjacent" fields which have since produced regularly more tons of cane per acre but with a considerably lower yield of sugar per ton than the checks which had no mud added to them. The results in these two cases are therefore *not* out of line. The owner remarked "I am surprised that there is not more difference in sugar content in favor of the check areas."

Trichogramma COLONIZATION EFFECTS UPON SUGAR PER TON OF CANE.—In addition to the foregoing studies, samples of cane were taken from as many of the test fields as possible to determine the average sugar content and the extent to which various degrees of borer infestation had affected the sugar produced. The method of taking samples was recommended by Professor W. G. Taggart, Assistant Director, Louisiana Experiment Station and in charge of Sugar Cane Investigations, as having been found to give consistently dependable field average analyses. The samples were taken by one man selecting at random 30 stalks scattered widely through the field and all analyses were made through the same mill and by the same chemist at the Louisiana Experiment Station.

In Table 5 we are able for the first time to present for 5 varieties the very significant correlations existing between borer infestation and the amount of sugar produced per ton of cane. Our investigations have included a much larger number of fields of POJ 213 cane than of any other variety because of the generally well known susceptibility of this variety to both borer attack and to red rot infection. The large number of fields represented gives the figures for sugar saved per ton of cane a very high degree of dependability for 213 (25.83 lbs.) and for the composite average for all varieties (20.92 lbs). The figures show also something of the variation which exists among cane varieties in susceptibility to injury by borer and red rot combined. Even with the variety CP 807 which appears in this table—and in all of our other studies—to be least injured in sugar content, the saving is sufficient to justify colonization work.

COST OF COLONIZATION WORK.—The cost of colonization work in 1932 ranged from about 80c to $1.20 per acre. A fair average figure covering the market cost of 6,000 parasites and the small amount of labor required in their liberation is $1.00 per acre. Very decided improvements have been made during the year in the type of container used in shipping out the unit numbers needed per acre.

SUMMARY AND CONCLUSIONS

1. In corn, among 8 comparable check fields the natural parasitism increased between June 15 and July 30 from 17.4% to 53.5% average (an increase of three-fold), while among 11 colonized areas averaging 16.3% parasitism before colonization, the addition of 6000 *Trichogramma* per acre enabled these fields to show 82.8% average parasitism at the end of July (an increase to five-fold).

2. Among the *cane* fields compared, the natural parasitism occurring at the start was 6.9% in all checks, 11.3% in all colonized and 3.3% in all adjacents which received most of their parasite supply from nearby, colonized corn fields. In three weeks the percentages had increased five-fold in colonized, five-fold in adjacent and three-fold in checks. Through the balance of the season the parasitism in colonized and adjacent areas continued far higher than in the checks, averaging approximately 28% above checks to Sept. 10.

3. Correlation studies show that in all check areas there was an average of 31.8% of the cane joints bored and a moth population of 6,057 produced in millable cane through the season. Compared with these figures all colonized fields showed 13.5% of joints bored and 3,422 moths per acre while adjacent fields had 12.3% of joints bored and 2,164 moths per acre.

4. With an initial total stand averaging 34,880 sprouts in all 31 protected areas and 35,720 in 28 checks, there were 19,289 millable stalks per acre produced in checks and 25,288 in all protected areas. The difference of 6000 millable stalks per acre, or a saving of over 30% of the check stalk yield, is indicated as one benefit from colonization work.

5. Finally, we find a consistent and very significant saving in pounds of sugar produced per ton of cane. The *saving* ranges from 6.52 lbs. per ton with 807 (the most resistant variety) to 25.83 lbs. per ton with 213. The general average saving shown as a composite of all varieties was 20.92 lbs. of sugar per ton of cane.

6. The cost of colonization work averaged $1.00 per acre in 1932.

7. Louisiana cane growers may depend upon this method of borer control, which has shown consistent benefits during each of the past six seasons. The measurement of actual benefit has been shown more clearly, fully and convincingly in 1932 than through the work of any preceding year.

8. Our general conclusion from all of this work is that *Trichogramma* colonization, as tested by Experiment Station workers and practiced by numerous growers in 1932, resulted in a very substantial reduction in cane borer multiplication and damage to sugar cane, and a corresponding increase in tonnage of millable cane and in the amount of sugar produced per ton of cane.

TECHNIQUE IN THE MASS PRODUCTION OF *TRICHOGRAMMA*

By E. Graywood Smyth, *Consulting Entomologist*

Abstract

A simple and cheap method is described for rearing *Trichogramma* in very large numbers. The economic soundness of biological control of cane borer by this method is attested by the success of the results obtained. The various advantages of the method over others that have been put forward are enumerated. Beyond its simplicity, the principal advantage claimed for the method is the ease with which restocking of moth breeding houses is accomplished.

Notable strides have been made in the past five years in the artificial propagation and use of the egg parasite, *Trichogramma*, to control such serious crop pests as the cane borer, the rice moths, the codling and Oriental fruit moths, and others. So extensive has become the use of the parasite, in widely separated parts of the globe, that the economic question of reduction of cost involved in its handling is a matter of great concern to those agencies who utilize this method of biological control. Any simplifying of the technique of mass production which reduces handling, and thus reduces cost, may be considered a step forward.

The author has been engaged for three years in control of the cane borer, *Diatraea saccharalis* Fab., on a large commercial scale by this method. The technique here described was very largely devised from experience gained during that time. Significant is the fact that, as a result of mass colonizations of *Trichogramma* wasps reared by this technique, borer damage was so reduced that the purity and sucrose of the cane (and hence the sugar content) showed a very considerable increase, in a large series of fields colonized with parasites, over those registered in other fields of the same plantation not so colonized. These conclusions were not arrived at from small samplings, but from official company figures of total yields. A study of costs and amortization has shown the system of biological control to be economically sound. Far from discontinuing the work after a three year trial, it is being increased by doubling the parasite rearing capacity.

The method of securing the oviposition of the wasps in petri dishes has faithfully served its usefulness, and is being displaced by other methods that involve less manipulation. A method recently devised by Flanders, in California, by which egg cards in multiple rows are slid into a box specially constructed for oviposition, which accom-

modates up to five million eggs at one time, serves very well where parasites are to be shipped, or are intended for use in orchards where the egg cards are suspended in trees. For control of the cane borer on large sugar cane plantations, however, the technique here described has been found both simple and expedient.

Mason jars are used, and the *Sitotroga* eggs are secured to the glass on the inside of jar by means of an aqueous solution of gum arabic, which is preferable to paste because odorless and perfectly clear. A little benzoate of soda is used to preserve the adhesive, which is painted in on one side of the jar with a long handled brush. It is painted in a series of bands crossing one another at right angles, so the deportment of the wasps may be later observed in the clear squares between the bands. Five or six disks of filter paper clamped on beneath the glass top of jar make a parasite proof cover. A minute or so after the adhesive is applied, a given number by weight of *Sitotroga* eggs is introduced, cover clamped on and the jar shaken well, which distributes the eggs evenly over the pasted bands. Jar is left open half an hour for the adhesive to dry, and is then inverted mouth to mouth over a similar jar containing parasitized *Sitotroga* eggs from which the Trix are about to or beginning to issue. (Jars containing many living Trix may be opened and handled without loss of parasites by placing a jar with bottom end toward strong light, when the wasps all flock to that end.) The jars are effectively secured together by means of a strip of adhesive tape (such as J. & J.) half an inch wide and ten inches long, bound about the circumference of the mouths and overlapping equally the lips. Stretched slightly, the tape takes advantage of the slight flare on the lips of jars, gripping them very tightly together. There is no loss of parasites. We use Atlas E-Z Clamp quart jars, and two jars thus bound together may be handled considerably without separating.

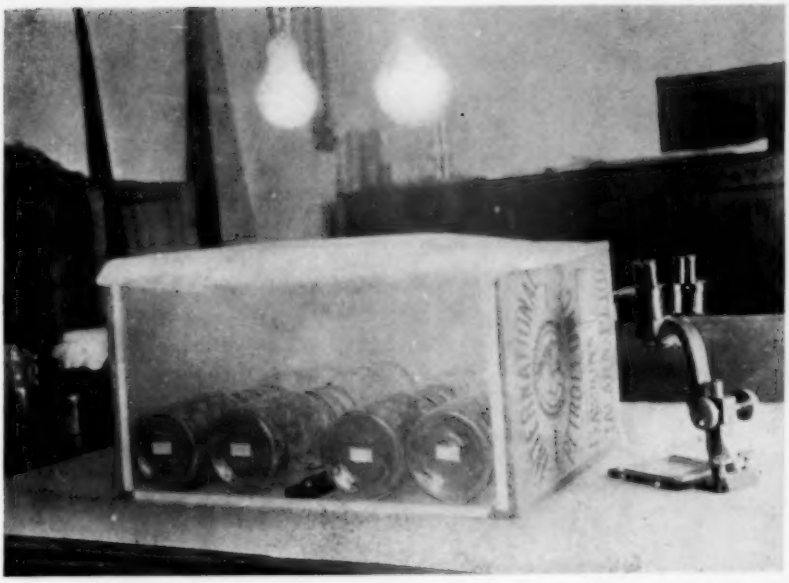
The two superimposed jars are placed in diffused artificial light for 24 hours, in a temperature of 29 degrees Centigrade, that with fresh eggs uppermost as the wasps crawl upward and have a tendency to remain near the top. Or the jars may be placed horizontally in a wooden box having three sides removed and replaced with thin paper, beneath artificial light, in which case the jars of parasitized eggs should be covered with dark cloth or carbon paper, so the wasps will pass into the jars of fresh eggs. Plate 33, Fig. 1, shows a lighting unit thus arranged, the carbon paper having been removed to show all the jars. Care should be taken to protect the jars, during

oviposition, from direct sunlight or even daylight, which tends to cause too much activity of the parasites and to draw them away from the eggs.

Before separating, jars are placed with the bottom of the one which contained the hatching Trix toward strong light, when most of the wasps will swarm back into it from the jar of fresh eggs. It is then detached and covered as described, with disks of filter paper, and is ready to be taken to the field for liberation of the parasites. The number of Trix lost through dying within the 24 hours, or from having remained in the other jar, will rarely exceed 15 to 20 per cent of the total, and is often less (many Trix will not have issued within the first 24 hours after hatching begins), and the fresh eggs, in number about equal to those in the jar that contained the wasps, will have become now mostly parasitized.

A calculation is easily made of the number of Trix to be liberated. Four small rectangles (about 3 by 12 mm.) are inscribed over the eggs on the outside of glass with India ink, so distributed as to give representative counts, and the number of parasitized and of unparasitized eggs within each rectangle is recorded. From these counts is derived the average parasitism of the eggs in the jar, and thus the number of parasites contained. Deducting 20 per cent of these for the losses sustained during oviposition gives a fairly accurate figure of the number to be liberated. If greater accuracy is desired, another simple method may be used. When pasting the eggs, 80 per cent of a lot may be secured against the glass on inside of a jar and 20 per cent pasted on a card, which is inserted in the same jar at time of oviposition. Thus if 200 thousand eggs are to be exposed to Trix in a jar, 160 thousand should be pasted as described against the glass on inside, and 40 thousand pasted on a card that is inserted in the same. When all are well parasitized the card is isolated in another jar, and kept for use in reovipositing, while the jar that contains 160 thousand is taken direct to the field when the wasps hatch. Thus the exact number of Trix liberated may be known.

After the separation of two jars bound together for oviposition, that with fresh eggs is bound in same manner with adhesive tape in inverted position over a jar containing fumigated corn, or other suitable grain, and thus left for six days. (See Plate 33, Fig. 2.) In this way the *Sitotroga* eggs that have not become parasitized by the Trix are not lost, but the larvae hatching from them are salvaged and later returned to the *Sitotroga* breeding rooms, and such living wasps



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1—Simple and economical lighting unit for use during oviposition of the wasps in the propagation of *Trichogramma*.

2—Jars of *Sitotroga* eggs inverted over jars of corn to conserve the larvae hatching from such eggs as may not have become parasitized.

as may remain in the jar will continue ovipositing. This saving of larvae from the unparasitized *Sitotroga* eggs is an important feature of the method. If a jar contains 100 thousand *Sitotroga* eggs and 15 per cent of the eggs have failed to become parasitized by the Trix (the usual parasitism ranges around 85 per cent), and we allow for a failure of perhaps a third of these to hatch through mechanical injury, it still means that something near ten thousand *Sitotroga* larvae are being returned to the breeding rooms from a single jar of eggs, that would be lost by most other methods. (A quart Mason jar will hold somewhat over two thousand grains of corn, which is sufficient to bring to maturity ten thousand *Sitotroga* moths.)

An estimate of the value of this saving is simple. If the weekly *Sitotroga* egg production is three million eggs, and that number is weekly subjected to Trix attack (on the basis of five jars daily of 100,000 eggs each), the weekly recovery of *Sitotroga* larvae from unparasitized eggs will be in the neighborhood of 300 thousand. It requires just about 200 thousand *Sitotroga* moths to produce three million eggs, at the average rate of 15 eggs per moth (or 30 eggs per female). Thus, if we are taking from the breeding houses only 200 thousand moths per week, but are returning 300 thousand young *Sitotroga* larvae per week, we are automatically more than sustaining the reproductive powers of the moths, and egg collections can continue indefinitely until the grain is exhausted.

A turning of five full jars of infested corn daily into the *Sitotroga* breeding rooms amounts to about an addition of four bushels monthly. This might result in a crowding of the grain bins unless adequate provision be made for the addition, so that it presupposes a sort of rotation in the filling of the bins with corn. It has been found expedient to start with bins about half full only; then, when fresh larva-infested corn is added, space is easily made for it, and the date of adding the corn is placed on the box. If one is using the type of breeding rooms designed by Hinds and Spencer (which contain bins of sliding boxes, like drawers, built in 8 tiers of 8 boxes to the tier, the boxes containing a bushel of corn each and the room thus holding 64 bushels), and the breeding is started with boxes only half filled, corn may be added at the rate of two bushels per month to each room for a year or more before crowding necessitates a removal of some of the used corn. The continued addition of infested corn to the bins, however, and the uninterrupted breeding of the moths, are predicated

upon the ability of the operator to keep his breeding houses free from contamination.

The breeding of *Sitotroga* moths in great quantities from grain, simple though it may appear, becomes very soon hampered by the invasion of other grain pests that are very undesirable for our purposes, in spite of all precautions that may be taken. Frequent opening of the door in the removal of eggs permits unavoidable entrance of other insects. These may include other grain moths, like *Ephestia* and *Plodia;* one or more of the grain beetles, *Calendra, Cathartus, Silvanus, Tribolium, Araecerus, Rhizopertha* and *Tenebrioides;* various species of mites that attack the moths; and Hymenopterus parasites of *Sitotroga.* Avoidance of these undesirable visitors becomes a question of the ability to eliminate them when they appear and before they cause trouble, and requires alertness and ingenuity. These questions we have successfully solved, and they will be discussed in another paper.

Another requirement, to accomplish uninterrupted breeding of *Sitotroga,* is the control of humidity in the breeding houses. It must be maintained at a level high enough to keep the corn from becoming too dry, so that young *Sitotroga* larvae may enter the corn at all times, but not high enough to cause molding of the corn. This is not really difficult to accomplish, with proper construction of the houses, and without the costly devices of electric thermostatic control and suction or ventilating fans. Success in insect control on a commercial scale demands great economy, and one learns soon to eliminate costly equipment.

When the jar of newly parasitized eggs is removed from over the jar of corn, it is capped in a different manner from that described above. A disk of filter paper is shaped to conform with the mouth of jar by pressing the glass cover tightly over it. Removing cover, the paper is secured by stretching over it, encircling the mouth and gripping the filter paper just below the lip, one of the rubber bands supplied with the jars. This makes a cover permitting slight ventilation, and permeation of moisture but no escape of parasites. The jar in this condition is laid in a sufficiently warm place (27 to 29 degrees Centigrade) with bottom of jar toward the window to avoid escape of parasites in event that an accident may puncture the filter paper, and thus remains for the ensuing few days until adult wasps begin to issue.

Caution should always be observed in the matter of temperature and humidity, as *Trichogramma* wasps in the immature stages are very

sensitive to both. In a temperature maintained between the extremes of 26 degrees (night) and 31 degrees Centigrade (daytime), the strain of *Trichogramma* native to the coastal districts of Peru requires but 8 to 9 days to pass from egg to adult, yet a slight lowering of the mean temperature may result in lengthening the term of life cycle by several days. Excessive humidity is especially to be avoided in the close confinement of the glass jars, and is apt to result when too direct a source of light is used during the oviposition. It is almost sure to prove fatal to the wasps. In short, while the technique here described may be depended upon to serve admirably in *Trichogramma* propagation if properly handled, it is the little "tricks" in the game, which can be learned only by costly experience, that spell real success or failure. One should never lose sight of the fact that in *Trichogramma* he is dealing with an extremely delicate insect, and one very responsive to slight changes of temperature, humidity and light.

The advantages of the jar method as here described may be summed up as follows:

(1) A jar may contain up to a quarter of a million eggs, so that simplicity of handling, and advantage over petri dishes or egg cards, are evident.

(2) As Trix seek the light during activity, they are in constant contact with the eggs against the glass, and oviposition is not neglected, but made very easy.

(3) Eggs are thoroughly protected from contact with, or damage by any exterior object, as well as from undue variations of humidity.

(4) Parasitized eggs are easily counted without touching them by marking small rectangles with India ink on the outside of jar, then counting the proportions within the rectangles.

(5) Transfer of the Trix without loss from one jar to another is very easy by reason of the positive phototropism of the wasps.

(6) Jars are very durable, and loss from breakage is rare, unlike the petri dishes.

(7) Salvage of all the *Sitotroga* larvae from unparasitized eggs is facilitated.

(8) Release of the parasites is simplified. Walking down the windward side of a cane field with an open jar of parasites in each hand may release a very large number of wasps in a short space of time, without danger of their mortality from any source.

(9) There is no loss of "expendable property" except in an occasional renewing of the adhesive tape. Jars of exhausted eggs are

quickly washed and reused, so that six to eight dozen jars will handle all the eggs one can produce from a hundred bushels of corn.

(10) The jars of corn containing *Sitotroga* larvae salvaged from unparasitized eggs, when kept closed and intact, constitute a pure culture of the grain moth, and if set aside may be used for restocking the moth breeding rooms following any fumigation that may have been necessitated by an invasion of mites, weevils, or *Sitotroga* parasites. This eliminates the necessity of laying aside in refrigeration a quantity of *Sitotroga* eggs for the purpose, with its consequent curtailment of Trix production, and gains much time.

Since *Sitotroga* requires about 35 days to mature from the egg, one may keep on hand constantly (if sufficient jars are available) from 120 to 150 of these "pure culture" jars, capped with filter paper and rubber band, as they accumulate at the rate of 30 per week when parasitizing five jars of eggs daily. Only the jars in which moths have begun to issue need be dumped into the breeding rooms. Thus a pure culture regenerating stock of more than a million moths, in all stages of development, may be kept in constant readiness to meet any emergency.

SECOND REPORT ON THE EFFICIENCY OF BAIT TRAPS FOR THE ORIENTAL FRUIT MOTH[1] AS INDICATED BY THE RELEASE AND CAPTURE OF MARKED ADULTS

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Abstract

Tests of bait-trap efficiency were continued at Cornelia, Ga., in 1932 by releasing large numbers of marked oriental fruit moths within baited and unbaited peach orchards. Of 1,144 released on 33 different days before peach harvest in a 16-acre orchard baited with 400 traps, 76.4 per cent were recovered; the females had deposited nearly 14 per cent of their eggs. Of 200 released before harvest in a 37-acre orchard baited with 2,200 traps, 89 per cent were recovered; the females had deposited 3.6 per cent of their eggs. Sixty to 80 per cent reductions in fruit injury were obtained in these orchards despite evident migration from more than 1,000 acres of surrounding unbaited orchards. After harvest the percentage of moths recovered from releases diminished, owing in some instances to migration

[1] *Grapholitha molesta* Busck.

out of the baited orchards before oviposition began. Of 492 moths released on 17 different days after peach harvest in the 37-acre orchard only 41 per cent were recaptured. The females had deposited 17.5 per cent of their eggs. An indication of the extent of interorchard movement was obtained by the release of 1,978 marked moths in unbaited peach orchards at distances varying from 75 yards to 1¾ miles from baited orchards. Sixteen flights of more than one-half mile and 100 of more than one-fifth mile occurred. Flights of 9,900, 9,400, 9,250, 7,250, 6,000, 5,900, and 5,300 feet were recorded, three of them before harvest, and four of them between baited orchards. The longest was by a female which deposited eggs after her capture. Releases made on four sides of the 37-acre baited orchard, one-fourth mile from the nearest traps, were followed by recoveries of 3.5 to 17 per cent. Releases made on two sides of the 16-acre orchard, one-eighth mile from the nearest traps, were followed by recoveries of 18.8 and 28.4 per cent. The experiments indicate that bait-trapping on a large scale, if properly conducted, should give satisfactory results. Baiting on a smaller scale may eventually become practicable if more efficient baits can be developed. The recoveries were made by experimental baits mixed among each other. Many were almost useless. They maintained an average attractiveness 65 per cent less than the best in the 16-acre orchard and 40 per cent less than one of the best in the 37-acre orchard.

Previously reported experiments[2] in which marked oriental fruit moths were liberated in baited and unbaited peach orchards and captured again proved that migration between orchards was so extensive that the actual infestation reduction within treated orchards could not be taken as a full measurement of bait-trap efficiency.

Although the degree of control to be obtained within the area baited is of first importance, nevertheless the reduction obtained in adjacent unbaited orchards can not be ignored, especially since the evidence indicates that the fruit moth population in almost any orchard is a menace to other orchards in the vicinity whether or not they contain bait traps.

It is apparent, therefore, that efforts at artificial control must include large acreages to be most successful. With the completion of large-scale experiments with bait traps for the oriental fruit moth at Vincennes, Ind., and Cornelia, Ga., in 1931 and the inauguration of more intensive studies to develop new baits and increase our knowledge of the insect's habits, the value of the marked-moth release experiments increased. The investigations reported herein were conducted at Cornelia during 1932.

[2]W. P. Yetter, Jr., and L. F. Steiner. A Preliminary Report on Large-Scale Bait Trapping of the Oriental Fruit Moth in Indiana and Georgia. Jour Econ. Ent. 24: 1181–1197. 1931.

W. P. Yetter, Jr., and L. F. Steiner. Efficiency of Bait Traps for the Oriental Fruit Moth as Indicated by the Release and Capture of Marked Adults. Jour. Econ. Ent. 25: 106–115. 1932.

Methods of Experimentation

Marking of Adults.—The atomizer-dye method of marking the moths, as described in the previous report, was again utilized. Newly emerged adults were carefully sprayed with 1 per cent solutions of Spirit Violet or Spirit Blue or 1½ per cent solutions of Eosin or Brilliant Yellow, 95 per cent alcohol being used as the solvent. Too much of the dye solution was found to injure the moths, too little would not make all of them recognizable if recovered. All moths showing evidences of having been marked were brought to the laboratory for microscopical verification.

Determination of Egg Content.—The writers were assisted in the original studies concerning the egg content of oriental fruit moths by E. M. Livingstone and L. A. Zimmer at Cornelia in 1930 and 1931, respectively, and by E. C. Barr at Vincennes in 1931. Livingstone's examinations showed that few fully developed eggs began to appear before the second day and he found no evidence that oviposition occurred within 48 hours after emergence. Barr privately made more intensive studies than were possible in connection with his official duties and worked out the morphology of the reproductive organs of the female oriental fruit moth. He secured valuable data indicating that the recognizable egg content increased until 20 to 24 hours after emergence, at which time the moths contained their maximum number of immature eggs. He also found that fully developed eggs began to form in the ovarian tubes at this age in occasional moths.

In connection with the present investigations the writers dissected some 750 females for egg-content determination. Only those alive immediately before dissection were utilized, since it was found that after death and occasionally in aged moths there was a rapid breakdown of ovarian tissue, particularly at the tip of the vitellarium where the immature eggs are the smallest, which would thus make a reasonably accurate egg count impossible. In most instances the egg content as given is only approximate, for in tearing apart the tips of the ovarian tubes (normally four in each ovary) injury frequently resulted to the smaller eggs in one or more tubes. Usually the tubes each contain about equal numbers of eggs, especially before oviposition begins. The number in injured tubes was therefore estimated from the content of those which were not injured.

There is no evidence that additional immature eggs form after a moth reaches the age of 24 hours. It was found that low temperatures

delayed the formation of the first mature eggs and thus prolonged the preoviposition period. Females recovered from traps within 48 hours after their emergence were classified as preoviposition-period moths, since most of these fell into the traps during the evening hours when approximately 10 or 34 hours old. The most accurate egg counts can be made at this age. When the moths are older the condition of the ovarian tubes makes the smaller eggs difficult to recognize and some are missed. Egg deposition may therefore have been less in some instances than the egg counts indicated. The number of eggs deposited by the females before capture was estimated for each release by comparing the average number of eggs in all females with the average number in those captured during their preoviposition period.

In 1931 the preoviposition egg content averaged 141 per female, in 1932 approximately 200. The maximum number of eggs found in a female was 362. The greater egg content in 1932 is significant since it is probably one of the causes for the large infestation increase. Larger females usually contain more eggs, and with an abundant food supply larger individuals will be developed.

TYPES OF RELEASES.—Releases were of three types, as follows:

Type A—A group of moths liberated at a single point at one time. In addition to the number recovered, it was possible to study the rate and direction of dispersal and the age at which the moths were captured.

Type B—Several groups of moths, similarly marked, liberated at the same point on successive days. Recoveries from such releases gave a more accurate indication of what the traps were accomplishing and made possible the use of more moths, but prevented any record of the time interval between release and capture except for those recovered within 24 hours after the first liberation.

Type C—Several groups of moths, similarly marked, liberated at different points within the same orchard on successive days. This type gave the most accurate indication of bait-trap efficiency within the orchard during definite periods, but made impossible a determination of the distances traveled or the age of the moths when captured, except for those recovered within 24 hours after the first release.

POINTS OF RELEASE.—Releases of 4,095 marked moths were made between May 4 and September 11, 1932. Of this number, 1,978 were liberated within nine unbaited peach orchards at distances of from 75 yards to 1¾ miles from the nearest traps, and 2,117 within three of the four baited or partially baited orchards described below.

The largest of the baited peach orchards called the Wade Area (Fig. 56), included 37 acres of Georgia Belle and Elberta and was bounded on all sides by unbaited peach and apple trees.

It contained 2,200 traps, in which 47 different bait solutions were being tested. Each tree in every second pair of rows contained a

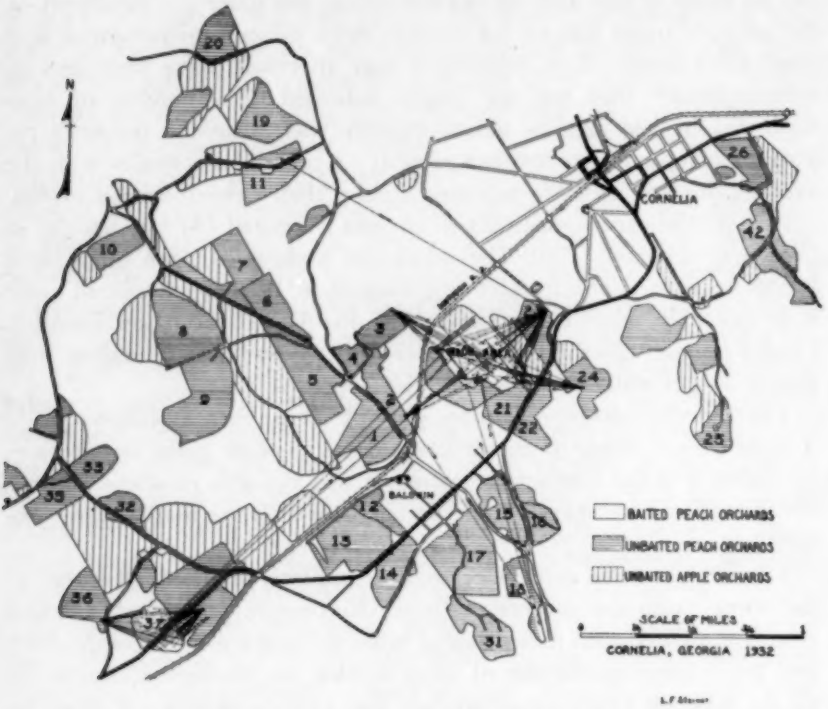

Fig. 56.—Experimental baits were tested in 1932 in the Wade Area, Orchard 37, Orchard 18, and Orchard 11. Points of release and capture for all inter-orchard flights originating within baited orchards or at points more than one-eighth mile from traps are indicated. (In 1931 two moths flew more than 6,000 feet from Orchard 25 to the Wade Area.)

trap of the wide-mouth, glass-jar, screen-covered type. In a test area of this sort the average efficiency of the baits naturally was less than that of the better solutions which might be recommended for commercial use. The 2,200 traps captured 37,614 unmarked moths after the cessation of spring-brood emergence, or an average of 17 per trap. Two hundred of the traps each contained 1 cubic centimeter of emulsified terpenyl acetate in a 10 per cent medium soft sugar solution used as a check bait; these captured an average of 27.4 moths per trap.

The second largest baited orchard, No. 37, also contained test baits that had an average efficiency much less than that of the check bait. This was a 16-acre Elberta orchard containing 400 traps, each tree in every fourth row being baited. These traps captured 17,843 unmarked moths, an average of 44.6 per trap, while the terpenyl acetate-medium soft sugar bait in this orchard averaged 127.7 per trap. No point in the orchard was more than 400 feet from an outside boundary.

Orchard 11, in which one release was made, contained 20 to 35 traps, which were being utilized to compare the relative efficiency at different ages of two very attractive baits. The traps were distributed in a single row, one to every second tree.

Orchard 18 was the fourth orchard baited. No moths were liberated there after 96 traps were placed in 24 of its trees.

Discussion of Results

Release Experiments in Baited Orchards.—The results of all releases made within baited orchards are summarized individually in Table 1, and collectively in Table 2. Brief supplementary notes on these releases follow:

Nos. 1–3. Weather fair. No. 1 was made in a quarter of the orchard baited with relatively unattractive granulated sugar-aromatic combinations. All recaptured moths flew into adjacent blocks where more attractive baits were located. Release No. 2 resulted in the first and only 100 per cent recovery. Eighty-nine per cent were recaptured within 48 hours.

No. 9. Weather fair until June 8, rainy from 8th to 19th. Again there was a definite movement of moths from the groups liberated among the granulated-sugar baits to the areas containing brown-sugar combinations.

Nos. 10–11. Showers during afternoon and evening occurred on 11 days during the recovery period. With an interchange of the two types of bait combinations between their areas the direction of moth movement was reversed, the moths flying into the new brown-sugar blocks.

No. 20. Weather warm and generally fair except for two rainy nights.

No. 21. Rain on all except three afternoons or evenings. Temperatures at dusk never less than 72°F.

No. 24. Made after harvest. Rain fell while three of the four groups of moths were being liberated. Three moths from this release were recaptured in the Wade Area, 1¾ miles northeast, after making minimum flights of 9,900, 9,400, and 9,250 feet. Two were females.

No. 13. Showers occurred at dusk or during the afternoon on all except three days of the recovery period. On June 21, 104 moths were liberated and on the 23rd, 96. Recoveries for the first four days, beginning June 22, were, respectively, 7, 50, 68, and 35 moths.

No. 22. Weather rainy. Release made near end of peach harvest.

No. 23. Showers daily from August 10 to 20. Twenty-five per cent of the recoveries were made among 17 per cent of the traps along the boundaries of the orchard. Most of these recoveries were along the short side adjacent to the young Hale orchard in which the "nubbin" crop was ripening.

No. 28. Weather fair. Captured moths well distributed over area.

Nos. 5, 6, 7, 8. Release of moths marked with four colors among 20 traps was followed in two hours by a severe windstorm, the average velocity exceeding 14 miles per hour and occasionally reaching 25 miles per hour, with some rain near dusk.

TABLE 1. RESULTS FROM RELEASES OF MARKED ORIENTAL FRUIT MOTHS IN BAITED ORCHARDS AT CORNELIA, GA., 1932

Release No.	Dates released	Release type	Orchard	Point of release	Number of moths released	Number of moths recovered		
						Males	Females	Total
1	May 4	A	No. 37	Center	17	8	4	12
2	May 5	A	No. 37	Center	28	19	9	28
2	May 6	A	No. 37	NE. center	66	38	19	57
9	May 30–June 10	C	No. 37	12 points	321	114	137	251
10	June 16–18	C	No. 37	3 points	85	28	27	55
11	June 19–23	C	No. 37	5 points	229	94	84	178
20	July 13–19	C	No. 37	7 points	200	66	72	138
21	July 25–27	C	No. 37	3 points	198	72	83	155
24	Aug. 15–18	B	No. 37	Center	120	13	12	25
13	June 21–23	B	Wade	Center	200	84	94	178
22	July 28–29	B	Wade	N. center	58	14	19	33
23	Aug. 8–13	C	Wade	6 points	200	39	37	76
26	Aug. 31–Sept. 5	B	Wade	Near S. side	163	38	26	64
28	Sept. 9–11	B	Wade	Center	71	15	14	29
5, 6, 7, 8	May 9	A	No. 11	Center	161	42	49	91

Release No.	Per cent of moths recovered	Day of last recovery[1]	Average number of eggs in—		Maximum distance (feet) traveled	Average distance (feet) traveled by—		
			Pre-ovip.[2] females	All females		All Moths	Males	Females
1	70.5	8th	186.0	169.2	375	204	146	318
2	100.0	11th	180.3	168.8	400	145	142	151
3	86.3	8th	192.8	174.2	550	122	117	131
9	78.1	12th	192.2	169.9				
10	64.7	11th	205.8	128.8				
11	77.7	16th	205.8	163.5				
20	69.0	6th	192.0	176.7				
21	78.2	10th	229.2	199.2				
24	20.8	8th	[3]	180.4	9,900	1,322	928	1,747
13	89.0	7th	193.3	186.3	850	175	160	188
22	56.8	8th	232.8	195.6	1,125	455	385	506
23	38.0	11th	196.4	158.2	6,000			
26	39.2	9th	200.0	175.3	1,200	358	220	560
28	40.8	10th	[3]	171.8	725	270	158	391
5, 6, 7, 8	56.5	7th	192.9	176.7	480	115	118	111

[1] After last liberation.
[2] Moths dissected before they had oviposited.
[3] Not possible to determine.

TABLE 2. RECAPITULATION OF RESULTS FROM RELEASES OF MARKED ORIENTAL FRUIT MOTHS MADE IN THE TWO PRINCIPAL BAITED ORCHARDS AT CORNELIA, GA., IN 1932

Orchard and time interval	Release No	Number of liberation points	Number of liberation days	Number of groups released	Number of moths released	Number of moths recovered: Males	Females	Total	Per cent of moths recovered
Orchard 37—									
Before harvest.....	1–3, 9–11, 20, 21	32	33	33	1,144	439	435	874	76.4
After harvest.....	24	1	4	4	120	13	12	25	20.8
Entire season.....	1–3, 9–11, 20, 21, 24	33	37	37	1,264	452	447	899	71.1
Wade Area—									
Before harvest.....	13	1	2	2	200	84	94	178	89.0
After harvest.....	22, 23, 26, 28	9	17	17	492	106	96	202	41.0
Entire season.....	13, 22, 23, 26, 28	9	19	19	692	190	190	380	54.9

Orchard and time interval	Number of females dissected	Number of eggs found	Average number of eggs in: Preovip. females	All females	Max. distance (feet) traveled	Number of moths having distance records	Average distance (feet) traveled by: All moths	Males	Females
Orchard 37—									
Before harvest.....	373	64,437	200.1	172.7	550	97	138	128	160
After harvest.....	9	1,624	(1)	180.4	9,900	25	1,322	928	1,747
Entire season.....	382	66,061	(1)	172.9	9,900	122	381	261	593
Wade Area—									
Before harvest.....	71	13,237	193.3	186.4	850	178	175	160	188
After harvest.....	62	10,823	211.5	174.5	6,000	127	407	325	502
Entire season.....	133	24,060	199.0	180.9	6,000	305	272	233	309

[1]Unknown.

In orchard No. 37 before peach harvest the recoveries ranged from 64.7 to 100 per cent. As shown in Tables 1 and 2, 76.4 per cent of the 1,144 moths liberated between May 4 and July 27 were recaptured. These moths had been released in 33 groups on as many days at 32 locations within the orchard. They had deposited an average of not more than 28 eggs per female or 14 per cent of their total. After peach harvest extensive migration occurred and only 20.8 per cent were recovered from the one release made in this orchard during August.

In the Wade Area but one release was made before harvest. Of 200 moths, 89 per cent were recaptured. The females had deposited an average of seven eggs each or 3.6 per cent of their total. After harvest 41 per cent of the 492 moths liberated on 17 different days between July 28 and September 11 were recovered. Recoveries for individual releases ranged from 38 to 56.8 per cent. These females had deposited about 17.5 per cent of their eggs before capture.

Release Experiments in Unbaited Orchards.—The results obtained from individual releases made in unbaited orchards are summarized in Table 3. These releases indicate somewhat the attraction that baited orchards have for moths emerging in surrounding unbaited orchards, and prove the ability of the oriental fruit moth to fly long distances. The point of release and point of capture for all moths known to have flown more than one-eighth mile to baited orchards during 1932 is shown in Figure 56. This includes four flights of more than a mile between baited orchards, in addition to three of more than a mile from unbaited to baited areas. Brief supplementary notes on releases made in unbaited orchards follow:

No. 4. Weather fair. Release made before the Wade Area or Orchard 18 was baited. The nearest traps were in Orchard 37, 1¾ miles west.

No. 12. Male captured on the fourth day after last release. Preceding three days were rainy. Flight was to nearest traps, 1 mile north.

Nos. 14–17. Weather fair. Wind shifting but generally from northwest. Releases made during the same period one-fourth mile from the Wade Area in four directions. Orchard 23 in very poor condition. Flights of more than a mile were made in opposite directions by two males.

Nos. 18–19. Weather generally fair. Wind shifting. Releases made one-eighth mile from opposite sides of Orchard 37, No. 18 among young unbearing trees and No. 19 among young trees bearing a crop (very similar to conditions in Orchard 37).

No. 25. Weather fair. No recoveries. Release made 1½ miles south of traps in Orchard 11, same distance west of Wade Area, and north of Orchard 37.

No. 27. Release made in Hale orchard southwest of Wade Area during rainy weather. Growth conditions at point of release very superior to Wade Area.

TABLE 3. RESULTS FROM RELEASES OF MARKED ORIENTAL FRUIT MOTHS IN UNBAITED PEACH ORCHARDS, CORNELIA, GA., 1932

Release No.	Date released	Release type	Points of release	Number of moths released	Number of moths recovered		
					Males	Females	Total
4	May 7–8	B	S. end Orch. 18	350	0	0	0
12	June 20, 22, 24	B	Center Orch. 18	375	1	0	1
14	July 8–12	B	Orchard 23	200	14	20	34
15	July 8–12	B	Orchard 24	200	6	4	10
16	July 8–12	B	Orchard 2	200	3	4	7
17	July 8–12	B	Orchard 3	200	7	5	12
18	July 13–14	B	⅛ mi. NE. of Orch. 37	88	18	7	25
19	July 13–14	B	⅛ mi. W. of Orch. 37	85	8	8	16
25	Aug. 19–24	B	Orchard 9	117	0	0	0
27	Aug. 31–Sept. 5	B	75 yds. SW. of Wade A.	163	16	3	19

Release No.	Per cent of moths recovered	Day of last recovery	Average egg content (number)	Maximum distance traveled		Average distance (feet) traveled by—		
				Feet	Direction	All moths	Males	Females
12	0.2	4th		5,900	N.		5,900	
14	17.0	13th	203.0	7,250	NW.	1,973	2,384	1,685
15	5.0	9th	130.0	3,200	W.	2,037	2,877	1,655
16	3.5	6th	171.2	5,300	SE.	2,452	3,006	2,037
17	6.0	6th	178.4	3,150	SE.	1,958	2,247	1,554
18	28.4	11th	188.8	1,400	SW.	1,075	1,058	1,117
19	18.8	9th	165.1	1,700	E.SE.	1,240	1,281	1,200
27	11.6	7th	304.0	1,450	E.	647	525	1,300

FACTORS AFFECTING MIGRATION AND BAIT TRAP EFFICIENCY

METEOROLOGICAL CONDITIONS. — Wind direction appeared to have little effect on direction of flight within baited orchards. Because of the length of some flights into baited orchards, the impossibility of determining the exact route followed or the elevation at which the flight was made, and because wind direction at tree-top level was not always the same at the different points under observation, the effect of wind direction on long flights could not be ascertained. However, if made at tree-top level most of them were against or across the wind.

Bait traps can function only while the adults are active. Activity is most affected by light intensity, with the optimum conditions prevailing during the hour at dusk and the hour at dawn. In these two periods nearly 75 per cent of the moths were captured, and most of the others entered the traps immediately before or after these hours. If certain weather conditions, such as rain, wind velocities in excess

of 10 miles per hour, or temperatures below 60°F., occur at these times, activity for the entire day may sometimes be prevented. Complete darkness and bright sunlight, except on rare occasions, will prevent activity. Warm moonlight nights and dull cloudy days may permit it. Low temperatures which prolong the preoviposition period but do not entirely prevent activity give the traps a longer period in which to capture the moths before oviposition begins. The prevention of activity by weather conditions other than low temperatures is likely to force an accumulation of fully developed eggs in the females, with the result that more of them may be deposited before the moths react to the baits. Females have been observed to alight on a leaf, oviposit, and fly away in two seconds, and in captivity one female has deposited as many as 40 eggs in one-half day.

ENVIRONMENTAL CONDITIONS.—The percentage of moths recovered from releases was reduced somewhat as a result of mortality from unfavorable weather conditions, the actions of predatory insects, and injury from the dyes. Evidence indicates that it was also reduced by moth migration out of the baited areas. At the same time there was a replacement of emigrating moths by others attracted into the area to the traps, so that the proportion of ovipositing females captured should be greater than the recoveries indicate, especially late in the season.

During the forepart of the season, when new twig growth and developing fruit was abundant, no known flights between baited areas occurred, flights within baited orchards were relatively short, and a large proportion of the marked moths were recaptured near the points of release during the preoviposition period. Furthermore, the distribution of native moth captures over the orchards was uniform, egg deposition before capture was comparatively slight, and the efficiency of the bait traps apparently very high.

Twigs were hardening as the fruit began to ripen. No change in adult behavior, as indicated by the recovery experiments, occurred until Release No. 22 was made in the Wade Area when harvest was about completed. Before the recoveries from this ceased the only fruit remaining in the vicinity of the orchard was the Hale "nubbin" crop adjacent to, and southwest of, the baited block. The 56.8 per cent recovery from Release No. 22 was lower than from any made in the two large baited orchards until that time but higher than any made after harvest. Immediately after harvest interorchard movement became more extensive.

The long-distance flights from Orchard 23 to Orchard 11, from the Wade Area and Orchard 2 to Orchard 18, and from Orchards 18 and 37 to the Wade Area indicate that conditions at the point of origin were not attractive enough to hold all the moths during their preoviposition period. Their subsequent recapture in areas supposedly less attractive in some instance than those they left suggests that their flights were originally stimulated by something other than the odors from the areas they were captured in, but that their responses to these stimuli changed after they passed through their preoviposition period. In the case of one moth the flight of 7,250 feet to Orchard 11 (which had only 30 traps) was made before harvest from an unbearing orchard making poor growth to a bearing orchard in very good condition. The fact that Orchard 23 was in poorer condition than Orchards 2, 3, and 24 may account for the greater recovery in the Wade Area from Release No. 14 than was obtained from Releases 15, 16, and 17. Likewise more migration occurred from Release No. 18 to Orchard 37 than from Release 19, possibly because the former was made in an unbearing orchard. After harvest a flight was made, from the Wade Area, 6,000 feet south to Orchard 18, which had less than 5 per cent as many traps and was in no better condition. At about the same time the three flights of 9,900, 9,400, and 9,250 feet were made to the Wade Area from Orchard 37. In the latter orchard growth conditions were much superior to the Wade Area but inferior to conditions in some of the intervening orchards. The longest of these flights was made by a female which, after capture, was confined in an oviposition jar where it deposited 14 eggs before becoming too weak to continue. Upon dissection it was found to contain 99 additional eggs.

During August, before removal of the Hale "nubbin" crop adjacent to the Wade Area, there was a definite movement of marked moths to that side of the orchard. Likewise the native population, as evidenced by location of the captures, concentrated there. Immediately after removal of the "nubbins" this movement ceased and distribution of the catches became more uniform. Incidentally, the removal of the 1932 crop at harvest was thorough, so that little or no fruit remained in the orchards.

After harvest fewer moths were captured during their preoviposition period, and movement within baited orchards averaged twice as far as before harvest.

Usually within baited orchards the females flew farther than the

males but in migration to baited orchards the males averaged the greater distances. Recoveries from releases made more than one-eighth mile from traps in unbaited areas (Fig. 56) were uniformly distributed over baited blocks, suggesting that these flights were more or less continuous or were made at a higher elevation, in contrast to flights from near-by releases which more frequently end as soon as the moths reach the edge of the area baited. Incidentally, in the Wade Area 9 per cent of the traps contained the terpenyl acetate-medium soft sugar bait and captured 17 per cent of the 84 marked moths attracted from outside the area.

The behavior of the moths both before and after harvest indicates that in the absence of fruit or succulent twigs there is a more than normal migration within two or three days after emergence and before the reaction to bait odors and the urge to oviposit become pronounced. It can not be prevented by the baits now in use, although it appears that when the moths begin ovipositing some may be attracted back to the orchard from which they migrated. The attraction by apple orchards probably increases adult movement after peach harvest, although the three longest flights between Orchard 37 and the Wade Area must have been made over the mile and a quarter of unbaited peach and apple trees between.

Fruit Moth Injury in Baited and Unbaited Orchards

It was not possible to secure accurate records of fruit injury during the 1932 season. The external examination of nearly 24,000 fruits, however, provided approximate figures which are of interest.

An extremely light crop of Elberta in the Wade Area averaged 12.3 per cent visible wormy fruit, while a crop averaging four times as large per tree in the unbaited orchards was 31.6 per cent wormy. The ratio of worm entrances in fruit per tree between the two areas was approximately 1 to 10. The fruit in Orchard 37 was also 12.3 per cent wormy, although during 1930 and 1931 this was one of the most severely infested of the unbaited orchards. A normal crop of Georgia Belle in the Wade Area was 1.8 per cent wormy as compared to 10.3 per cent for Belle in unbaited orchards.

The Wade Area was not baited until after spring-brood emergence had ceased. In 1931 its Elberta fruit was 0.5 per cent wormy, after the orchard had been baited, as compared to nearly 5 per cent injury to fruit in unbaited orchards, yet in 1932 the first-brood larval damage to twigs with one exception was greater than in any of the nine or-

chards with which it was compared. This can be accounted for only by a movement of spring-brood moths into the area where twig growth, at that time, was more succulent than in adjoining orchards. Despite this and the extensive migration into baited areas, as evidenced by the release experiments, the percentage of wormy fruit in the two principal bated orchards was less in 1932 than in any one of the 12 unbaited orchards in which fruit infestation records were secured. As further evidence that interorchard movement tends to equalize the moth distribution over a considerable area, the orchards baited in 1931 but not baited in 1932 and those unbaited both seasons averaged 32.8 and 30.9 per cent wormy fruit, respectively. The infestation ratio between the same orchards in 1931 was 1 to 9.3. Likewise the orchards in which twig injury made the most marked increases were those which had been baited in 1930 and 1931 and left unbaited in 1932. The increase over 1931 was 5.9 times, as compared to 2.3 times in those never baited. There was practically no increase in twig growth in either group.

Conclusion

The release of 1,144 marked oriental fruit moths on 33 different days before harvest in a 16-acre orchard baited with 400 traps indicated that these traps were capturing 76 per cent of the emerging adults. Before capture the female moths had deposited nearly 14 per cent of their eggs. There was an apparent reduction in wormy fruit of not less than 60 per cent as a result of the bait-trapping despite the use of baits which captured an average of only 35 per cent as many moths per trap as the best tested in the orchard, and despite extensive migration from adjacent orchards into this small area. The release of 200 marked moths before harvest in a 37-acre orchard baited with 2,200 traps indicated that as high as 89 per cent of the moths were being captured, and after harvest the release of 492 moths on 17 different days indicated that the baits were capturing 41 per cent of those emerging in the area during this period. Previous to harvest the recaptured moths had deposited 3.6 per cent of their eggs, after harvest, 17.5 per cent, before they were caught.

It appears that the use of one trap per two trees permits less oviposition before capture than the use of one trap to four trees. The reduction in fruit injury in the larger baited orchard was greater than in the smaller one.

The release of 1,978 marked moths in unbaited orchards proved that migration to baited or between baited orchards was extensive. Other evidence indicates that it is extensive between unbaited orchards and that the absence of fruit or succulent twig growth stimulates flight during the preoviposition period to other areas. Seven flights ranging between 1 and nearly 2 miles were recorded during 1932. A female which had flown a minimum distance of 9,900 feet deposited eggs after capture. This flight was made between two baited orchards. One hundred flights of more than one-fifth mile and sixteen of more than one-half mile were made. The four baited orchards, of which approximately 60 acres contained traps, very probably attracted moths from more than 1,000 acres of peach trees, since this acreage is located within one mile of one or more of them. For the same reason the number of moths migrating into the baited orchards may have been greater than the native population.

Large-scale bait-trapping should give satisfactory results. Baiting on a smaller scale may eventually become practicable if more efficient baits can be developed. At present, large-scale operations, using approximately 50 traps per acre or one per two trees, should not cost more than $7.25 per acre for the season at Cornelia. The development of more efficient baits which will make possible the use of fewer traps per acre will reduce this cost.

ORIENTAL FRUIT MOTH PARASITES IN MICHIGAN[1]

By J. M. MERRITT,[2] *Section of Entomology, Michigan State College*

ABSTRACT

A report on the activity of the native parasites of *Grapholitha molesta* Busck in Michigan orchards since 1929. Data are presented showing an average parasitism of 30 per cent for a period of three years. Twenty-one species of parasites have been reared, 82 per cent of which were *Glypta rufiscutellaris* Cress. Considerable seasonal variation in the fruit moth population is shown, apparently not closely correlated with the activity of the parasites.

The oriental fruit moth, *Grapholitha molesta*, Busck, was first reported in Michigan the fall of 1928 from a commercial peach orchard

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[2]Experimental work in control of the fruit moth was begun in 1929 under the supervision of L. G. Gentner, Research Assistant in Entomology, and subsequently continued under the supervision of Ray Hutson, Associate in Research in Entomology.

in Washtenaw county. The following year experimental work was started in that orchard on the control of the pests. The appearance of parasitism in this orchard, as shown by rearing and field observation, indicated that native parasites might be of importance in the early development of an infestation.

Beginning in 1930 regular collections of twigs injured by the fruit moth were made in a nearby orchard which was severely infested. The twigs were caged in the field insectary and the larvae allowed to complete their development on apples. Daily recoveries of parasites were made as soon as they started to emerge. This procedure supplied data on the prevalence of the fruit moth in the orchard, as well as on the parasites.

In 1932 the procedure was extended to include another orchard, in which the infestation had become large enough to permit practical study.

Through the kindness of R. A. Cushman and C. F. W. Muesebeck of the United States National Museum, final identification of all parasites has been made, with the exception of the *Glypta rufiscutellaris* Cress., collected in 1932.

During the season of 1929, the following six species of parasites were reared, for the most part, from cocoons collected on the trees: *Aenoplex betulaecola* Ashmead, *Cryptus alacris* Cresson, *Ephialtes aequalis* Prov., *Hoplocryptus incertulus* Cushman, *Idecthis nigrocoxalis* Cushman and *Dibrachys boucheanus* Ratz.

Summarized data on the relative abundance and importance of the fifteen different species reared during 1930, 1931, and 1932 are presented in the following tabulation:

These data show that *Glypta rufiscutellaris* Cresson, has been the most important parasite reared, over 80 per cent of all parasites being of this species. *Cremastus minor* Cushman was somewhat active in 1931, while recoveries of *Pristomerus ocellatus* Cushman, and *Dioctes obliteratus* Cresson were more common than has usually been reported. Several other species were active at certain times, but the variation in their activity from year to year was considerable.

Glypta rufiscutellaris has shown the least variation in its seasonal activity. This species has consistently been recovered from the larval collections made in the first part of the second generation of the fruit moth, varying from the 1st to the 15th of July. The peak of parasitism has occurred during this generation, about the last of July, except in 1931, when parasitism of the third brood approached 75 per cent. The

ORIENTAL FRUIT MOTH PARASITES—RELATIVE ABUNDANCE AND EFFICIENCY IN WASHTENAW COUNTY, MICHIGAN, DURING THE PERIOD 1929 TO 1932

Species of parasites	1930 Number of individuals emerged	1930 Percentage of larvae parasitized	1930 Percentage of all parasites	1931 Number of individuals emerged	1931 Percentage of larvae parasitized	1931 Percentage of all parasites	1932 Number of individuals emerged	1932 Per centage of larvae parasitized	1932 Percentage of all parasites	Average Number of individuals emerged	Average Per centage of larvae parasitized	Average Percentage of all parasites
Glypta rufiscutellaris Cress.	17	6.8	68.0	149	23.1	73.0	448	29.2	90.1	614	25.2	82.1
Cremastus minor Cush.				45	7.0	22.1	2	0.1	0.4	47	1.9	6.3
Pristomerus ocellatus Cush							13	0.8	2.6	13	0.5	1.7
Cremastus forbesii Weed.				6	0.9	2.9	6	0.4	1.2	12	0.5	1.6
Macrocentrus delicatus Cress.	5	2.0	20.0				5	0.3	1.0	10	0.4	1.3
Dioctes obliteratus Cress.	1	0.4	4.0	2	0.3	1.0	7	0.5	1.4	10	0.4	1.3
Ascogaster carpocapsae Vier.				1	0.15	0.5	4	0.26	0.8	5	0.2	0.7
Bassus cinctus Cress.							1	0.07	0.2	1	0.04	0.13
Calliephialtes grapholithae Cress.							1	0.07	0.2	1	0.04	0.13
Cremastus tortricidis Cush.							2	0.14	0.4	2	0.08	0.26
Epiurus indagator Cress.	1	0.4	4.0							1	0.04	0.13
Macrocentrus ancylivorus Roh.				1	0.15	0.5				1	0.04	0.13
Meteorus trachynotus Vier.	1	0.4								1	0.04	0.13
Microbracon gelechiae Ashm.							*5	0.07	1.0	*5	0.04	1.3
Microbracon mellitor Say.							3	0.2	0.6	3	0.12	0.4
All other parasites (1929)										22	0.9	2.9
Parasitism of larvae by all species	25	10.0	100.0	204	31.6	100.0	497	32.11	100.0	748	30.44	100.0
Number of fruit moth larvae	251			646			1,537			2,434		

*These parasites emerged from one fruit moth cocoon.

parasitism of the first generation has been slight except in 1931, when parasitism by *Cremastus minor* was approximately 20 per cent.

A study of the larval population of the fruit moth in this orchard for the same three seasons indicates that the second generation has been considerably larger than the first, and that after the second generation there has been a great decrease in the larval population, with the result that the fruit infestation has been uniformly low; in fact, it has never reached 2 per cent. This decrease in population has coincided with the increase in activity of the parasites, but apparently cannot be attributed wholly to their effect, for the percentage of parasitism of the second generation has never been great enough to warrant the resulting decrease in larval population. In 1931 the parasitism of the second generation was 18 per cent, and the reduction in the orchard population of the fruit moth was 76 per cent from the second to the third generations, while in 1932 the corresponding figures were 12½ per cent and 75 per cent. Therefore, in this orchard, factors inhibiting the development of the fruit moth have in part made possible the high percentage of parasitism, which has occurred during the latter part of the season.

The results obtained during the summer of 1932 from another orchard are of interest in this respect: The infestation in this orchard of 150 acres had been slowly developing since the fall of 1929, the young, thrifty trees making conditions very favorable. The first brood was large in 1932, and as *Glypta rufiscutellaris* Cress. had been reared from collections made in this orchard in 1931, the parasite was expected to develop rapidly under the favorable host conditions. However, no recoveries of parasites were made until the second generation of the moth appeared. The second brood tripled the larval population, and during this period the parasitism increased to 34 per cent, nearly all by *Glypta rufiscutellaris*. The fruit moth population continued to increase and caused serious injury to the fruit, in contrast to conditions in the other orchard.

In spite of the increase in the larval population, parasitism had practically ceased at the end of the second brood. Large collections of injured twigs were made in the orchard, coincident with the emergence period of the parasites of the second brood. These collections indicated that the parasitism was negligible, and that several species were responsible. Apparently factors other than the prevalence of host material govern the activity of *Glypta rufiscutellaris* after the second brood of the fruit moth.

Summarizing these data, it may be said that the native parasites of the

fruit moth, particularly *Glypta rufiscutellaris* Cress., have been active to a considerable extent in Michigan since the introduction of the pest. All species combined have averaged a parasitism of 30 per cent for the last three years. It should also be evident that until more data are available on the factors governing the parasite-host relationships affecting their seasonal activity, probably little can be done in evaluating their economic importance.

EFFECT OF DUSTS ON THE ORIENTAL ROACH

By GEORGE L. HOCKENYOS[1]

ABSTRACT

A technique is described which was used to determine if very fine dust would enter the tracheae of the Oriental Roach (*Blatta orientalis*). Neither submergence in a dust nor suspension in a dust charged atmosphere caused dust particles to enter the tracheae. It is suggested that loss of moisture might account for the injurious effect of dusts on some insects.

There are numerous references in the literature of insect control to the possibility of inert dusts effecting the destruction of certain species of insects by a mechanical clogging of the spiracles. The following experiments were an attempt to determine if such a phenomenon could be observed with the Oriental roach (*Blatta orientalis*).

Individual roaches were stuck fast in an inverted position by means of paraffine. This was easily accomplished by putting a few drops of molten paraffine on the small end of a cork stopper. The dorsal surface of the thorax was then pressed into the paraffine and cold water poured over the insect to quickly harden the paraffine. Specimens so prepared could be readily examined under a binocular to measure the opening and observe the action of the thoracic spiracles. That this means of handling them was not injurious was evidenced by the fact that some were kept so implanted for three days without apparent injury. Observed in this way, the thoracic spiracles are seen to be protected by a flap-like valve which can open to give an unobstructed entrance into the spiracles or can be closed tightly. In the observed cases of respiration, the valve actually opened only a small part of its possible extension. Accurate measurement of the opening is difficult, but it may be said that a clearance of from 25 to 50 microns occurred in the observed operation of

[1]Contribution No. 156 from the Department of Entomology, University of Illinois. By Geo. L. Hockenyos.

the valve; and when turned back by a dissecting needle point the opening exceeds 200 microns. The larger trachea in the thoracic region measure approximately 250 microns in diameter in an adult Oriental roach. The abdominal spiracles are so depressed between the edges of the sternites and pleurites that no satisfactory measurements were obtained.

A sample of pure magnesium carbonate was obtained and found to consist chiefly of particles from 1 to 10 microns in size. A pint fruit jar was half filled with this material and five Oriental roaches placed therein. The jar was slowly tumbled for ten minutes so that the roaches were kept completely submerged. They were then removed to a large jar for observation. Their movements were considerably slower than those of some control roaches, but they were all alive at the end of 54 hours. Two specimens were then killed and the thoracic spiracles examined. There was no evidence of obstruction even though the dust had adhered to all parts of the body. The insects were dissected and the larger thoracic trachea examined microscopically. No evidence of dust particles could be found.

It was noted in dissecting these specimens that they had become so desiccated that there was no free body fluid. This condition could easily account for the relative inactivity of the insects and might be attributed to the action of the magnesium carbonate in absorbing and evaporating the body moisture.

A special dusting machine was constructed as follows: A series of tin pipes each 30 inches long and of 4 sizes, namely, 2 inches, 4 inches, 9 inches, and 30 inches in diameter, were arranged vertically on a common axis with the smallest on the bottom and the largest on the top. They were connected tightly and a piece of heavy piano felt stretched over the top of the uppermost pipe.

Ten roaches were placed in a screen cage and suspended in the center of the largest pipe. After the felt was put into place, a stream of air carrying magnesium carbonate dust was blown into the small pipe at the bottom of the vertical series of pipes. As the air stream expanded through the successively larger pipes, its velocity decreased and successively smaller particles of the carbonate were deposited on the shoulders where each pipe expanded into the larger one above. The felt retained practically all of the dust particles, and by lifting a corner of this covering momentarily it could be seen that the largest pipe was filled with an extremely dense atmosphere of very fine dust particles. These particles were collected on a microscope slide and found to measure from 1 to 4 microns in diameter.

The roaches were left in this machine for two hours while a slow stream of air charged with dust was blown in at the bottom. When removed from the machine they were observed to be covered with a very light coating of dust particles but seemed quite active. One of the ten was killed and dissected as soon as removed from the dusting machine, but no dust particles were found in the trachea. The other nine were kept under observation for three days and seemed quite as active as the controls.

Ten roaches were similarly treated in the dusting machine, but a clay dust containing 10% derris resin was used and the time of dusting reduced to 20 minutes, after which the roaches were individually freed from as much dust as possible by means of an air blast and soft brush. This latter precaution was taken to prevent their possibly ingesting enough derris from the antennae or legs to cause death. These insects seemed unaffected at the end of two days and the experiment was discontinued.

The evidence of these three tests would indicate that in the case of the Oriental roach dust particles even of very small size do not enter the thoracic spiracles, and the derris dust must not have entered any of the spiracles. Such injury as results from very heavy dusting is probably due to the desiccating action of the dust, since heavily dusted specimens suffered great loss of body moisture as compared to controls.

THE NEW MEXICO RANGE CATERPILLAR AND ITS NATURAL CONTROL

By V. L. WILDERMUTH, *Senior Entomologist*, and J. C. FRANKENFELD, *Associate Entomologist, Division of Cereal and Forage Insects, Bureau of Entomology, U. S. Dept. of Agriculture*

ABSTRACT

The New Mexico range caterpillar, *Hemileuca oliviae* Ckll., after approximately 12 years of restricted activities, has again reached damaging numbers and has spread over the entire cattle-range area of northeastern New Mexico. Control is being attempted through breeding and colonizing its native egg parasite.

A study of the rise and fall in abundance of the New Mexico range caterpillar, *Hemileuca oliviae* Ckll., is of special interest as a striking example of the interrelation of insects and their enemies. The range caterpillar is confined to an area located mostly in northeastern New Mexico, where it feeds on the range grasses. The center of infestation includes the five northeastern counties of the State and embraces a

district having its extreme outside limits about 200 miles apart. Adults have been taken in southern Colorado and northwestern Texas, and larvae have been observed in the Panhandle district of Texas. Its past history is somewhat vague, but there are excellent grounds for believing that it has been a pest in northeastern New Mexico since that part of the country was settled in the last century.

The insect occurs in abundance over a period of approximately 10 to 12 years, after which it seems to be practically absent for a period of approximately the same number of years. Information furnished by ranch owners and others has revealed the fact that there was an outbreak from 1885 to 1895, with the peak probably occurring about the year 1892. This outbreak was apparently not brought to the attention of entomologists. Two outbreaks have been observed by entomologists of the U. S. Department of Agriculture. The first of these was reported to the Department in 1908. It had doubtless been in progress for a period of three or four years before it was reported, and it persisted until 1916, when the caterpillars became so reduced in numbers as to remain unnoticed for a period of about 10 years. The second is the present outbreak, which began in 1926. During the summer of that year a limited number of caterpillars were noted in an area of only a few square miles near Wagonmound, N. Mex., but they probably occurred in other isolated areas. The insect gradually spread from such areas until the past season (1932), when the caterpillar again seemed to be approaching its peak of infestation and was found distributed over practically the entire district. In many places they were extremely numerous while in others they occurred in limited numbers or were entirely absent.

The development of the caterpillars in large numbers over a wide area in the present outbreak has been influenced by climatic conditions that have tended to delay the peak of infestation. In the fall of 1929, caterpillars occurred in extremely large numbers in many places and it was predicted that the following year would witness a rather widespread outbreak. However, when these heavily infested territories were visited in May, 1930, it was observed that many eggs were late in hatching. Subsequently it was noted that a large majority of these eggs failed to hatch. It was first thought that this was due to the eggs having been killed by freezing during the previous extremely dry, cold winter, but observations made in subsequent years proved this surmise to be incorrect. Other observations have brought us to believe that this lack of hatching was due entirely to the infertility of the eggs. The cause of this condition has not been definitely decided but was likely due to

weather conditions at the time the moths were emerging in the previous fall. A snowfall approaching blizzard proportions accompanied by low temperatures prevented the mating of the moths. The males, having to a large extent issued from their cocoons preceding the females, were mostly dead by the time the weather moderated, and it is thought that many of the females thus oviposited without having been fertilized. The fertile eggs hatched extremely late in the summer of 1930, owing to dry conditions on the range. When sufficient rain fell for their hatching, the season was far advanced and, food being scarce, owing to a short growth of range grasses, the caterpillars did not reach a full-fed development at pupation. Female moths developing from these pupae were extremely low in vitality and consequently laid a smaller number of eggs, thus further retarding the multiplication of the insect to damaging numbers. Only this year, therefore, has it reached a wide distribution.

As has been mentioned, the outbreak of 1904 to 1916 was first brought to the attention of the Department of Agriculture in August, 1908. C. N. Ainslie carried to completion a thorough preliminary study of the life history of the caterpillar during the season of 1909, and a report of this study was subsequently published (1). In 1912, cattlemen in the district, being greatly alarmed at the widespread devastation caused to range grasses by the caterpillars, were instrumental in securing funds for detailed investigation and the possible control of the pest. These investigations were subsequently carried on from 1913 to 1916 by the senior author assisted by D. J. Caffrey and others (3). The work extended over a period of four years and, as previously mentioned, at the end of this time insufficient caterpillars remained to permit the continuation of the study.

The question naturally arises, Why does this insect become so extremely numerous and devastating and then suddenly wane in numbers so that one has to search for days and days before any caterpillars can be found? The answer to this is, Natural enemies, the chief of which, in 1916, was an egg parasite, *Anastatus samiflavidus* Gahan (2). This hymenopterous parasite was first noticed in the egg collections of 1913 at Koehler, New Mexico. Mr. Ainslie, in his studies in 1909, did not observe egg parasites and expressed great surprise when told that this species had been found. It seems quite likely that when Mr. Ainslie was making his study the parasite was present in only limited numbers, in isolated areas where it had maintained itself, and that it began its spread from these areas and was gradually increasing when first found

in 1913. Subsequently it developed in ever-increasing numbers until 1916, when eggs laid by the range caterpillar were found to be nearly 100 per cent parasitized by this interesting and valuable parasite. The apparent disappearance of the caterpillars on the open range in the following years is doubtless explicable in this manner.

Other natural enemies have been noted to assist in controlling this pest. Among the insect-control factors are two tachinids, *Tachina mella* Walk. and *Phorocera claripennis* Macq., which prey upon the larva; and two species of Hymenoptera, *Pimpla conquisitor* Say and *Chalcis ovata* Say, both of which parasitize the pupal stage of the caterpillar. Native beetles were also noted feeding upon both larva and pupa; the most conspicuous of these was *Calosoma obsoleta* Say. Other insect enemies of the pest, of minor importance, were encountered but it is unnecessary to mention them here since they have already been noted in former publications. Skunks were found to feed abundantly upon the pupae in many localities and exerted a considerable influence in reducing the numbers of the insects.

The range caterpillar was observed to return in damaging numbers in the summer of 1926, and it was noted during the years following that the pest was appearing each season in ever-increasing numbers. This led the Congress to put at the disposal of the Department of Agriculture a fund for investigating the control of the pest. Soon thereafter the senior author, in consultation with W. H. Larrimer, in charge of the Division of Cereal and Forage Insects, Bureau of Entomology, began the formulation of plans for attempted control.

In the investigation of 1913 to 1916 stress had been placed upon the introduction of parasitic or predacious insects as a possible means of control. Our efforts were concentrated quite largely on the introduction of the dipteron *Compsilura concinnata* Meig. and of three predacious beetles, *Calosoma sycophanta* L., *C. lugubre* Lec., and *C. calidum* Fab. The most promising of these beetles, *Calosoma sycophanta* L., was reared and distributed in large numbers. These insects, as is well known, had been of great value in assisting in the control of the brown-tail moth, *Nygmia phaeorrhoea* Don., and the gypsy moth, *Porthetria dispar* L., in Massachusetts and it was hoped that they might be of similar value against the range caterpillar. These were bred, reared, and released in large numbers, but observations showed that they had exerted only a minor influence in the control of the caterpillars. Knowing that the outbreak was finally terminated by the activities of the egg parasite, *Anastatus semiflavidus* Gahan, we now decided that a

promising control measure would be the artificial rearing and colonization of this insect. This egg parasite, after reducing the numbers of the range caterpillar, naturally itself becomes reduced to an almost negligible minimum. The caterpillars and parasites both seem to maintain their existence in small numbers in remote, out-of-the-way places in the range caterpillar territory. It was realized that the rise in abundance of the moths and their spread over a larger district occurs several years in advance of the increase in abundance of the egg parasite. Therefore it was argued that if we could find a few of these egg parasite in isolated spots, rear them in numbers, and colonize them at well-located points throughout the infested territory we could thus accelerate the speed of multiplication of the parasite and greatly reduce the period of years required for it to gain control of the range caterpillar.

The work was therefore begun and after much search we finally found eggs in the vicinity of Roy, N. Mex., that gave us 1.6 per cent parasitism. These eggs were taken to the U. S. Entomological Laboratory at Tempe, Ariz., and there, in a temperature-control chamber, the parasites were reared. From this small beginning, abundant rearings of the parasite were rapidly made and these have been distributed on the range caterpillar territory during the last two years. It remains for J. C. Frankenfeld and O. L. Barnes to discuss, in the paper that follows, the methods used in rearing this parasite.

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THE EQUIPMENT AND METHODS USED IN REARING THE NEW MEXICO RANGE CATERPILLAR PARASITE, *ANASTATUS SEMIFLAVIDUS* GAHAN

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ABSTRACT

This article contains a detailed description of the equipment and methods used in rearing and handling *Anastatus semiflavidus* Gahan under controlled conditions of temperature and moisture. Descriptions include a constant-temperature room, incubators, refrigerators, and oviposition cages.

When studies were begun early in 1930 at the Tempe, Ariz., laboratory on the control of the New Mexico range caterpillar, *Hemileuca oliviae* Ckll., by its egg parasite, *Anastatus semiflavidus* Gahan, it was deemed advisable to begin mass production of the parasite as quickly as practicable. Because of the extremely long, hot summers in southern Arizona and the probable desirability of a practically uniform temperature, the year round, for the breeding and rearing of the parasite, it was agreed that a constant-temperature room should be constructed and equipped. Accordingly, the room was built during the spring of 1930, and the heating and cooling systems were installed and in operation before the end of that year.

The constant-temperature room is a few feet to the rear of the laboratory building proper. It is 14 feet long by 9 feet wide by 6 feet 5 inches high, inside dimensions. A double wall containing an intervening 6-inch layer of pine sawdust surrounds the room. The same construction is used in the ceiling, while the floor is of one layer of 1-inch pine flooring. Pine ceiling material is used throughout with the exception of the floor and the outer overhead wooden layer, the latter being of 1 by 12 inch pine lumber. The entire room is covered by a gable-type roof of wooden shingles. The room may be entered through double wooden doors (inner and outer) 2 feet 6 inches by 6 feet in size. There is an air space of 3 inches between the inner and outer doors. The outer wall extends to the ground level, and the floor is about 4 inches above this level. The room is ventilated by means of a vent, 4¾ inches by 4¾ inches in size, located in the center of the top of the room, and by two openings in the floor. The floor openings are 10 inches by 12 inches in size and are situated at each end of the room, and approximately midway of the width. Two openings in the walls, one at each end below the floor level, allow fresh air to enter the floor openings. All openings are screen-covered to prevent entrance of insects, mice, or other small animals.

The air is kept in circulation by a 16-inch oscillating-type electric fan placed near one of the floor openings. The room is lighted by two 150-watt, daylight-type, electric-light bulbs projecting horizontally from the side walls about 6 feet above the floor and situated midway of the length of the room. Wall sockets are placed in relative positions in the ends of the room for convenient electrical connections.

The winter season in southern Arizona, is mild, yet it is necessary to supply artificial heat in order to keep conditions in a room suitable for the continuous breeding and rearing of *Anastatus semiflavidus*. During last season's studies it was desirable to keep the room at various constant temperatures ranging from 70° to 80°F. This was successfully accomplished by means of a thermal system substantially the same as is described by Baker and Arbuthnot (2). The same writers described a humidifier, and one of the same type is used at the Tempe Laboratory.

As the summer temperatures at Tempe regularly reach a maximum of 100°F., or above, it was necessary to install an effective cooling system if suitable temperatures for parasite rearing were to be obtained. To quite an extent, the selection and installation of the cooling system was of a pioneering nature; unusual climatic conditions, construction of room, and cost of contemplated systems were all factors which made the problem more complex. Specifications were finally completed, and the cooling system was purchased, installed, and put in operation in June, 1930. The system used is of the automatic electric type, consisting essentially of a 1-horsepower, 60-cycle, 110 to 220 volt motor; a two-cylinder, vertical, reciprocating, single-acting-type compressor capable of displacing 10,000 cubic inches at a speed of not more than 500 revolutions per minute; a water condenser; and two copper expansion coils, each with five fins, and measuring 3 feet 5¾ inches long by 15¾ inches wide by 19¾ inches high. The motor, compressor, and water condenser are mounted on the same cast-iron base which rests on the floor of a screened insectary room adjoining the constant-temperature room and within 10 inches of the outer wall of the latter. The expansion coils are situated in the west end of the room in tandem, approximately 20 inches from the west wall, and with a clearance of about 11 inches from the side walls at either end of the extended coil battery. The coils are suspended from the ceiling by means of iron braces and bolts. A drip pan immediately under the coils is 7 feet 3 inches long by 19 inches wide by 1 inch deep and is slightly lowered at one end to allow ready drainage. It clears the floor at approximately an average of 4 feet 9 inches and a hole cut in the lower end is connected by pipe with the

sewer. Two holes cut through the wall of the temperature-control room permit pipe connections between the expansion coils and the compressing machinery outside. Water connections to supply water for the condenser are made outside the control room near the compressing machinery. Sulphur dioxide is the refrigerating medium.

The original specifications demanded refrigeration equipment that would maintain a minimum temperature of 60°F, and a maximum temperature of 70°F., when the outside temperature is 100°F or above, with the machinery running no more than 14 hours out of 24. At no time during the summers of 1930 and 1931 has more than one of the expansion coils been in operation at the same time, and suitable temperatures for the purposes desired, 70° to 80°F., have been maintained. It appears likely that a materially smaller system would have fulfilled the need.

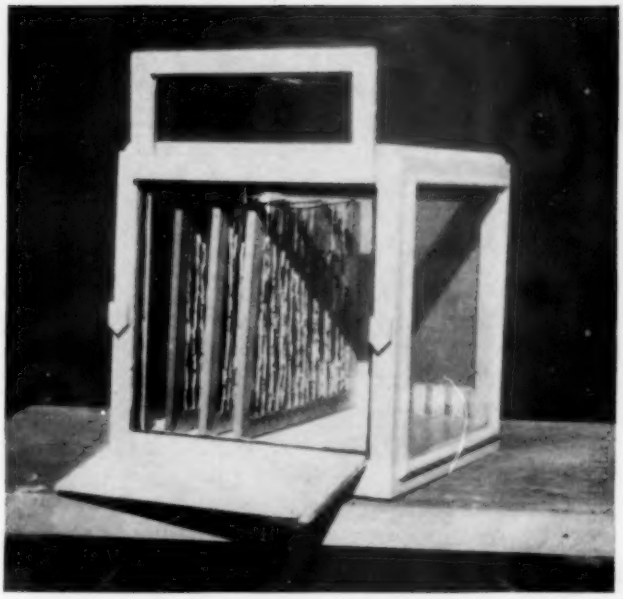
Large numbers of range caterpillar eggs must be kept in a practically dormant state for several weeks or even months both before and after parasitization by *A. semiflavidus*. This is accomplished by two automatically controlled electric refrigerators of the type used for household purposes, each having an approximate storage space of 4 cubic feet. No difficulty has been encountered in maintaining practically constant temperatures with these machines set to run at 35° or 40°F., the temperatures desired in the work to date.

Two automatically controlled electric incubators are used to incubate the parasitized range caterpillar eggs. Inside dimensions are as follows: Larger incubator, 15 inches high by 15½ inches wide by 14 inches deep; smaller incubator, 12 inches high by 10 inches wide by 12 inches deep. The incubators are constructed of asbestos transite with polished copper external trimmings. These incubators have a temperature range from room temperature to 158°F. For use in the range caterpillar work they have been satisfactory when run at desired temperatures of 80° to 95°F. Both incubators are equipped with removable shelves.

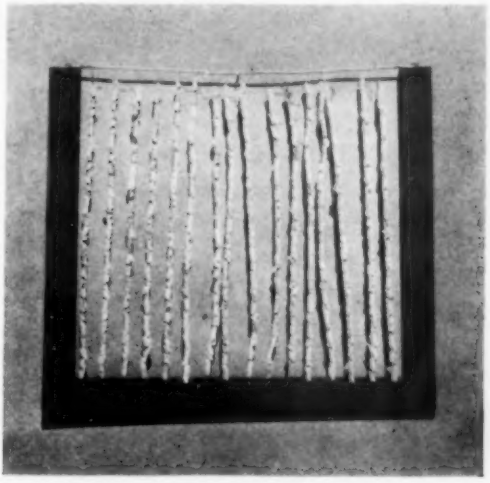
A refrigerator, the humidifier, and the apparatus for heating the temperature-control room are located near the east wall of the room. A shelf, 26 inches wide by 10 feet long and 2 feet 6 inches above the floor, extends along the north wall beginning at the west end of the room. This shelf is used for oviposition cages. A work table 25 inches by 8 feet extends along the south wall. The door is located on the south side of the room about 1 foot from the southeast corner. A considerable amount of storage space is available under the tables and shelves described.

The parasite oviposition cage (Pl. 34, Fig. 1) now in use is constructed as follows: There is a stout wooden framework. The inside dimensions, including space occupied by projecting framework, are 16 inches by 16 inches by 15 inches high. The top, two sides, and the upper door are covered with transparent celluloid. The back is covered with a layer of cheesecloth over which is placed a layer of 16-mesh window screen. The lower door is covered in a similar manner. (The screen permits access of fresh air and the cheesecloth prevents escape of the parasites or entrance of small insects.) The cage is provided with two hinged doors, one directly above the other, so that they meet at the middle of the front of the cage when closed. The upper door opens upward and the lower downward, and each is 6½ inches high and 13½ inches wide. The cage floor is made of beaver board. The exterior woodwork is painted gray and the interior is enameled white. The door facings have strips of felt pasted around them to prevent escape of parasites through small openings around the edges of the doors. Small wooden latches held on by screws and free to turn in either direction keep either one or both doors closed, as desired. A device to hold the egg racks approximately ¾ inch apart and in a vertical position is located in the back of the cage and rests on the cage floor. It consists of a bar of wood ¾ inch by 1¾ inches by 14 inches long placed edgewise so that the ¾ inch dimension rests on the floor of the cage. In the face of the bar toward the front are cut 11 notches ⅜ inch deep by ½ inch wide by 1¾ inches high. A horizontal interval ¾ inch wide separates each two notches. A space of ½ inch is left at each end of the bar. As the material in the egg racks is slightly less than ½ inch in thickness the ends of the racks fit into the notches snugly.

Each cage is made to hold a maximum of 11 egg racks. The racks are 14½ inches long by 12¼ inches high, the two ends and bottom of the frame made of 1-inch by ½-inch wood strips fastened together at the corners with corrugated fasteners. A stout wire nailed at the ends to the projecting wooden ends completes the framework. Along the lower side of the framework ¾ inch from the bottom are driven, at intervals of ¾ inch, 16 ½-inch small-headed tacks, the heads of which are allowed to project about ⅛ inch. Sixteen No. 28 bright iron wires, each approximately 12 inches long, are used to hold the eggs placed on each rack. A small loop is made at one end of each wire, which slips over the head of one of the tacks in the lower bar of the rack frame. After the cylindrical range caterpillar egg masses have been slipped over the wire and it is full, almost to the top of the rack frame, the upper



1—Oviposition cage used in breeding *Anstatus semiflavidus*



2—Egg rack

end is bent over the large wire at the upper side of the frame (Pl. 34, Fig. 2).

The New Mexico range caterpillar has one generation a year. The eggs, (*1, p. 65*) are deposited, during September, October, and November, in cylindrical masses around grass or weed stems near the ground (*4, p. 6*), and the species remains in this stage until the following May or early June. As the eggs are firmly glued together and tightly fastened to their support, and as the eggshells are very thick and durable, their handling is much simplified. The eggs are collected by breaking the grass or weed stem a short distance above and below the egg mass. Large numbers of these eggs are collected on the range in northeastern New Mexico from October to March and shipped or brought to the Tempe laboratory.

When the eggs arrive at the laboratory they are immediately placed in refrigeration at 35°F. until they are needed for use in breeding *A. semiflavidus*. As the eggs are needed in the breeding work they are taken from the refrigerator and the grass or weed stems removed; they are then placed on the small wires previously described, which are in turn put on the racks and then placed in the oviposition cage along with other racks of eggs. It is estimated that each wire will support approximately 1,250 eggs. With 16 strands of eggs to the rack and 11 racks to each breeding cage (full capacity) each cage would hold 220,000 eggs. In actual rearing operations only 10 racks, or 200,000 eggs, are placed in the cage at one time, the vacant space being used for food containers and boxes containing parasitized range caterpillar eggs from which *A. semiflavidus* are emerging.

The eggs in the oviposition cages are exposed to *A. semiflavidus* for a period of two weeks, and when highly parasitized are removed from the cages, left in the constant-temperature room three or four days, and then stored in a refrigerator at 40°F. until needed for replenishing stock in oviposition cages or for field liberation in New Mexico. Percentage of parasitism is checked by microscopic examination of the egg punctures on representative egg masses.

A high percentage of parasitism has been secured with a temperature of approximately 75°F. and an average relative humidity of approximately 80 per cent. From our preliminary observations, rather wide fluctuations in the percentage of relative humidity do not appreciably affect parasite activity or oviposition. Good results have been obtained with temperatures as low as 72°F. and as high as 79°F. Under laboratory conditions temperatures above 80°F. are unsuitable for oviposition.

Seven oviposition cages are now available. It is planned to keep six of these cages going all the time during the parasite-rearing period, which usually extends from October to May. This will permit changing the eggs in three cages each week, and allow one extra cage at all times for removing eggs, cleaning, and refilling. Each emptied cage is washed and aired before again being used.

In the field *A. semiflavidus* probably approaches one complete generation each year (*3*). Under controlled conditions it is very probable that six or more effective partial generations can be reared. The parasite has been reared from egg to adult in 21 days at 80°F. When incubation is at 80°F. emergence of the parasites is about at its height at 30 to 40 and gradually declines to 50 or 60 days, then practically ceases.

In the field many fully developed larvae of *A. semiflavidus* remain in the host eggs for two years, and a few for even three years. Under controlled temperature and moisture conditions we have a similar situation, many of the fully developed parasite larvae remaining in the host eggs for several months after emergence has apparently stopped.

Because of irregular emergence and overlapping generations, it has been impossible to work out and follow a definite system in stocking or restocking oviposition cages with parasites. In general, the observation and judgment of the worker, aided by parasitization counts, have determined the number of adult parasites to be used in oviposition cages. The parasitized eggs in small cardboard boxes in lots of 10,000, 20,000, or 30,000 are incubated at 80° to 85°F. until parasites are rapidly emerging. They are then removed from the incubator and placed along one side of the oviposition cage, one or two egg racks usually being left out to make room for these eggs. If emergence is very rapid and a high concentration of females is noticed in a cage, the stock material is removed to a new cage, placed in a cage where the number of parasites is declining, or removed to a cooler temperature to retard emergence. When the emergence rate declines rapidly the eggs are again incubated for a few days and returned to an oviposition cage. When parasite emergence is almost negligible the remaining parasitized eggs are placed in storage at 40°F. to be used later for field liberation. Moistening the eggs occasionally with an atomizer apparently hastens emergence.

A solution of honey water (honey 1 part and water 3 parts) was supplied as food for the parasites. Cotton plugs fastened to corks are soaked with this solution, and are suspended through openings in the ceiling or top of the cage. Each cage is provided with six of these feeding plugs, which are usually supplied with fresh food every three days.

A high degree of success has been obtained with this equipment. Adult female parasites have been kept alive for three months, during which time as high as 355 host eggs have been parasitized by individual females. Provided sufficient host eggs are readily available, it is possible to obtain approximately two million parasitized host eggs per month, during the parasite rearing season (November to March).

To date some six million parasitized host eggs have been returned to the range in northeastern New Mexico, and examination of these liberated host eggs shows that from 85–90 per cent of adult parasites have emerged.

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NEW DEVELOPMENTS IN THE CONTROL OF THE CHERRY CASE BEARER (*COLEOPHORA PRUNIELLA*, CLEM.) IN WISCONSIN

By J. H. LILLY and C. L. FLUKE, *Department of Economic Entomology, University of Wisconsin*[1]

ABSTRACT

In past years, control of the cherry case bearer, *Coleophora pruniella* Clem. by dormant oil emulsion sprays has been quite successful on cherries but often failed almost entirely on apples. High percentages of kill on apples were made in 1932. The keynote to successful case bearer control is shown to be thorough spraying from the ground. However, applications thorough enough to give a satisfactory kill often give excessive tree injuries in the Door Peninsular fruit growing area. Dormant lime sulfur was tried in an effort to control this insect without tree injuries, and preliminary trials with it are most encouraging.

The cherry case bearer, *Coleophora pruniella* Clemens, has in recent years become the most important orchard pest in the Door Peninsula fruit-growing area of Wisconsin. Its seriousness is due to a most

[1]This paper is published with the consent of the Director of the Wisconsin Agricultural Experiment Station.

unusual degree of specialization for its own survival. Its body is well protected by a tough case constructed from leaf tissue and it feeds entirely as a semi leaf-mining insect. Its successful control on cherry trees in the past has been followed by the adoption of the apple as host by a majority of the population.

In the past, experimental work on the control of this insect has been largely on cherry trees. Work on cherries in both Wisconsin (2, 4, 5, 9, 12, 13) and Michigan (6, 7, 8) has shown that 6% and 8% strengths of lubricating oil emulsions applied in the dormant stage in the spring gave quite satisfactory control. In Wisconsin, this work was initiated by Granovsky (4, 5) and has been continued by the writers (2, 9) while in Michigan Hutson (6, 7, 8) is responsible for the published work. Although these workers have used three somewhat different methods of checking their results, the kill on cherry has been consistently between 80% and 98% when a dormant oil emulsion spray was properly applied.

When control was attempted on apples (2, 8, 10, 11) it resulted in more or less unsatisfactory kill, even when the same oils were used and similarly applied. This was true in both experimental plots and commercially sprayed orchards. Observations in 1931 indicated that the low kill on apples might be due to any one or more of the following factors: First, cases constructed from apple leaves may be more impermeable to oil sprays than those made of cherry leaf tissue. Second, on apple branches, the cases are often scattered along on the under side of the limb rather than being entirely concentrated about the small crotches as on cherries. Third, the smooth, waxy cherry bark causes the oil to collect in large drops in the small crotches where the hibernating cases are clustered instead of a rather uniform oil film enveloping the entire tree as it appears to do on apples. Fourth, extremely windy conditions prevailed during the time when the 1931 applications were made. The last two factors were probably by far the most important.

In view of these facts, our efforts in 1932 were largely concentrated on controlling the case bearer on apples. Although other materials were tried, most of the work was centered around oil sprays of various types, as they had given control on cherries and are comparatively economical.

METHODS.—Our 1932 oil spray plots were located in one orchard near Sturgeon Bay, and practically all were of the Wealthy variety. The sprays were carefully applied so as to give every limb a complete coverage, and were always sprayed from the ground so as to hit the branches from the lower sides where most of the hibernating cases are

TABLE OF RESULTS WITH OIL SPRAYS ON APPLES—1932

Plot	Materials	Rate	Results 1st count	Results 2nd count	% kill	Remarks
–	Check	—	15,599	8,996	0	42.3% "dead"
1	Kerosene	10%				
	Soap	—	6,824	3,177	19.3	Plots 1 to 4 inclusive sprayed in late fall for a comparison of fall and spring applications.
2	"Diamond Paraffin"	7%				
	"Kayso"	1–100	7,700	1,208	72.8	
3	"Barko"	8%	7,520	240	94.5	
4	"Dendrol"	8%	6,520	258	93.1	
5	"Tiara"	8%				Commercial spraying.
	"Kayso"	1–100	4,816	368	86.8	Medium coverage.
6	"Kayso"	1–100	9,110	73	98.6	Very thorough spraying. Heavy coverage.
7	"Spuria"	8%				Low viscosity oil.
	"Kayso"	1–100	8,797	249	95.1	Good coverage.
8	"Diamond Paraffin"	8%				Good commercial spraying.
	"Kayso"	1–100	8,401	333	93.1	Fair coverage.
9	"Diamond Paraffin"	8%				
	Bordeaux	4–4–50	9,638	689	87.6	Did not give good coverage.
10	"Dendrol"	8%	10,162	155	97.4	Gives excellent coverage.
11	L-1776	8%				
	"Kayso"	1–100	6,593	37	99.0	First of a series of seven oils of varying physical properties as explained below. They were kindly furnished by Mr. C. R. Cleveland of Standard Oil Co. (Ind.).
12	L-1777	8%				
	"Kayso"	1–100	6,797	7	99.8	
13	L-53	8%				
	"Kayso"	1–100	6,365	13	99.6	
14	L-1778	8%				
	"Kayso"	1–100	8,019	133	97.1	
15	L-1779	8%				
	"Kayso"	1–100	8,573	102	97.9	
16	L-93	8%				
	"Kayso"	1–100	7,917	129	97.2	
17	L-1781	8%				
	"Kayso"	1–100	5,094	380	87.1	
18	Kerosene	20%				Perfectly emulsified
	Soap	5–70	5,390	2,546	18.1	Gave good coverage.

located. Even then, partly due to changing weather conditions, some plots were more thoroughly sprayed than others. This will be brought out in the discussion. The "cold-mix" emulsions with "Kayso" were prepared in the spray tank as recommended by Granovsky (3) and the "Dendrol" was prepared according to the manufacturer's directions.

Results of the dormant spray applications were checked in the following manner. An original or total count was made while the tree and its case bearer population were still in the dormant stage, either before or after the spray was applied. Each count limb was selected on a different side of the tree and a substantial paper tag was securely tied to it at a point distal to which somewhere between 50 and 250 hibernating cases were roughly estimated to be present. The cases between the tag and the tip of the branch, including those on the spurs and twigs, were counted and the total number recorded on the tag. Three branches were always counted on each count tree so as to know how many tags to look for when making the second count. When a plot contained less than twenty trees, counts were made on all of them. The smallest plots consisted of 16 trees each.

The second counts were made about a month later when all of the larvae which were capable of doing so had moved to the leaves and started feeding. As it was much easier to count the live insects feeding on the leaves than to search for the dead ones on the branches, the live count was taken and recorded on the tag beneath the total or first count. Adequate counts were made on unsprayed trees. It is important to note that the average per cent "dead" was 42.3% on the unsprayed check trees. This is about the average natural mortality in Wisconsin.

When the figures from the tags were totaled, the per cent alive in each plot was computed. The control was then calculated by the Abbott (1) formula $\frac{X - Y}{X} \times 100 =$ per cent kill, where $X =$ the per cent living in the check and $Y =$ the per cent alive in the treated plot.

EXPLANATION OF TABLE.—The check was a composite taken from unsprayed trees in different parts of the orchard. It seemed desirable for uniformity to use a single figure based on large numbers as the check for all the plot calculations. This eliminated the larger probable error of small counts, as the mortality was fairly general throughout the orchard.

The first four plots were applied on November 11, 1931, as fall dormants. The trees appeared to be entirely dormant at that time, al-

though many leaves were still clinging to them. The day was favorable for spraying. The kill on these plots was not quite as satisfactory as when the same materials were applied in the spring. However, contrary to the results obtained by most other workers, their tree injuries were minimal as compared to the spring applications.

Plots 5 to 10 inclusive were tests made with different commercial proprietary petroleum oils to compare their relative effectiveness and to test various methods of application. The control secured in every plot was, to our best judgment, in an exact ratio to the thoroughness of coverage—the better the coverage the higher the percentage of kill. Plots 5 and 6 of 8% "Tiara" gave 86.8% and 98.6% kill when the only factor varied was the thoroughness of spraying. "Diamond Paraffin" 8% in plots 8 and 9 gave kills of 93.1% and 87.6% when emulsified with "Kayso" and Bordeaux mixture (3) respectively. The emulsifying agent was the only factor varied, but the Bordeaux emulsion did not spread and wet as well as that made with Kayso. These two pairs of plots were in each case applied side by side and on the same day. Both "Dendrol" and "Spuria" are excellent wetting oils. Good coverage and a correspondingly high kill were secured with both of them.

Plots 11 to 17 inclusive were planned so as to test oils varying in unsulfonatable residue, density, and specific gravity. This plan of attack was suggested by the results of Swingle and Snapp (14). Oils L-1776, L-1777 and L-53 gave tests in unsulfonatable residue of 68%, 82% and 96% respectively, while their viscosities ranged only between 80 and 85 by the Saybolt test. Oils L-1776, L-1778, L-1779, and L-93 gave viscosity tests (Saybolt) with ranges within 80 to 85, 100 to 105, 140 to 145, and 180 to 185 respectively, while their unsulfonatable residue was constant at 68%. Oils L-1776 and L-1781 had specific gravities of .8816 and .9071 respectively, while the unsulfonatable residue of each was 68% and their viscosities ranged between 80 and 85 seconds Saybolt. These analyses were all kindly supplied by Mr. C. R. Cleveland. It will be noted that oil number 1776 was the first in each series. As these oils, with the exception of L-1781 with a high specific gravity gave kills ranging from 97.1% to 99.8%, the viscosity and per cent of unsulfonatable residue of the oil used are apparently secondary in importance to the thoroughness of its application in case bearer control. The importance of the specific gravity of an oil is doubtful. It will be noted, however, that plots 1 and 18 with kerosene emulsions failed to even approach a satisfactory control. Tar oil washes, such as "Barko," deserve more trials than we were able to give them this year.

DISCUSSION OF CONTROL.—It is now apparent that thorough coverage is the keynote to successful control of the cherry case bearer on apples. This was best demonstrated by the three series of oils of widely varying physical properties, all of which gave a satisfactory kill when thoroughly applied in 8% "Kayso" emulsions. Counts were also made where a grower used 8% "Tiara" in a very light application. He got only a 26.1% kill. Thus 8% "Tiara" gave 26.1%, 86.8%, and 98.6% kills on three different plots, the kill corresponding with the degree of coverage. The two "Diamond Paraffin" plots emulsified with different agents again emphasized the importance of coverage, the better-wetting emulsion giving a correspondingly higher kill. When a drop of the Bordeaux emulsion dried on a twig it always left a greenish residue. Observations showed that where this was abundant over a cluster of cases, all were killed, but where it was lacking many survived. The importance of coverage was still further substantiated by a count made where a grower applied "Barko", a proprietary tar oil wash in a 3.33% strength. He sprayed very thoroughly and got an 98.5% kill. The importance of good coverage is not to be unexpected when we consider that oil is supposed to kill by actual contact.

In spite of their high percentage of kill, petroleum oil sprays do not offer a satisfactory control of the case bearer in Wisconsin because of the hazard of tree injuries. Oil injuries in the past have been of such consequence that some orchardists refused to apply them at all, and most of those who have used them applied them so sparingly that satisfactory controls did not result. These oil injuries have been of three distinct types. First, the development of apple foliage in early spring was markedly delayed and in some cases the leaves on heavily sprayed branches were dwarfed throughout the season. Second, entire spurs or twigs occasionally were "burned" or killed by thorough applications on both apples and cherries. Third, some of the fruit buds were killed, thus lowering the fruit set on apples. This last type has not been checked on cherries. The first two types were readily and commonly noticeable, but the last was probably the most important. Dead blossom spurs were commonly seen when the second counts were made, and a really heavy set has never been observed where petroleum oil was heavily applied. Unfortunately, it is very difficult to definitely evaluate the importance of these injuries. Certainly they are always undesirable, especially on young trees. These injuries were more noticeable in the Door County Peninsula area than most workers have reported from other regions. Two factors are suggested which logically

seem to explain these differences. The soil in this region is quite shallow and the past two years have been more or less dry seasons, marked by a lack of soil moisture. It seems only logical that trees in this area were thus somewhat weaker than normal and subsequently more susceptible to oil injuries. This appears to be especially significant if oils, as is sometimes supposed, injure by blocking off the passage of plant sap to the twigs and leaves. Second, most other work with oil sprays has been done with concentrations lower than 8% and against insects less difficult to control. Evidences of oil injury have been observed with all the oils tried except "Barko" and kerosene.

Results with Dormant Lime Sulfur.—Dormant lime sulfur was tried on the case bearer for the first time this year in an effort to find a satisfactory kill and avoid tree injuries. A dormant application consisting of 10 gallons of Dow liquid lime sulfur to each 90 gallons of water plus arsenate of lead at the rate of four pounds to 100 gallons of spray was the only strength tried. The arsenate of lead was included, not to act as a stomach poison, but in hopes that it might make the lime sulfur more active and possibly make it more adhesive. This spray was thoroughly applied on about two acres of apples and three acres of cherries in a heavily infested area. They were sprayed in the late dormant stage when the buds were considerably swelled. The counts showed an 84.1% kill on apples and 86.5% on cherries. Absolutely no injury could be detected and both plots later appeared to have been even more completely controlled than the counts indicated. This work will have to be duplicated before the results are conclusive.

Acknowledgments.—The writers wish to express their sincere appreciation of the splendid cooperation rendered them by D. E. Bingham and son and L. P. Nebel, Sturgeon Bay, Wisconsin, orchardists.

General Summary and Conclusions

1. Thorough spraying from the ground will control the cherry case bearer (*Coleophora pruniella*, Clem.) on apples.

2. Dormant oil emulsion sprays have so far shown the best control.

3. Oil emulsions with the best spreading and wetting properties are most effective.

4. Dormant petroleum oil emulsion sprays are undesirable because of the following tree injuries:

a. Killing of some fruit buds, thus lowering the fruit set on apples.

b. Killing of entire spurs when applied in excess on both apples and cherries.

c. Delaying and sometimes dwarfing the development of foliage on apples.

5. Kerosene emulsions up to 20% strength fail to give control.

6. Dormant strength lime sulfur in the late dormant stage gives promise of a practicable control with no tree injury.

7. A tar oil wash has given good control with no evident tree injuries.

8. Dormant oil emulsion sprays applied in the fall gave less tree injury than the spring applications.

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INFLUENCE OF HOST RESISTANCE AND TEMPERATURE DURING DORMANCY UPON SEASONAL HISTORY OF THE WALNUT HUSK FLY, *RHAGOLETIS COMPLETA* CRESS.[1]

By A. M. Boyce, *University of California Citrus Experiment Station*

Abstract

Data obtained during a five-year biological study of the walnut husk fly, *Rhagoletis completa*, show that host resistance (particularly varietal susceptibility) is directly related to hardness of the walnut husk at the time of oviposition activity of the fly. Seasonal adult emergence is dependent upon the action of factors influencing the termination of dormancy, among which accumulated temperature appears to be of prime importance. A comparison of the seasonal history of the insect for the period 1928–1932 is graphically presented.

A five-year biological study of the walnut husk fly, *Rhagoletis completa* Cress., in California, has supplied very interesting information regarding the nature of host resistance and also the effect of accumulated temperature during dormancy upon seasonal emergence of adults. This species is no doubt indigenous to the central region of the United States, around the 100th meridian, where it occurs on wild black walnut (*Juglans* spp.). It was not differentiated from other walnut-inhabiting *Rhagoletis* until 1929, three years after it was known to occur in a small area in this state. It has risen from obscurity to become a major pest of certain of the more important commercial varieties of Persian walnut (*Juglans regia*).

Host Resistance.—Early in the history of this insect in its new habitat, it was recognized that certain varieties of Persian walnut were more susceptible to attack than others. An instance was recorded in 1928, and many similar ones have been recorded since, where over 95 per cent of the walnuts on Eureka trees were infested, while those on the alternately planted Placentia trees were only 2 per cent infested. In general the later-ripening, thick-husked varieties are most susceptible. Since the flies oviposited in the green husk tissue, varietal susceptibility appeared to be due to the physical nature of the husk, i. e., relative hardness at the time of oviposition activity. Accordingly studies were conducted each year from 1929 to 1932 inclusive, to determine the pressure in grams required to puncture the husks of the several varieties of walnuts during the oviposition period of the fly. The entire data

[1]Paper No. 278, University of California Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

comprised a total of over 35,000 punctures. A modified Jolly balance was used to determine husk hardness (Fig. 57). Typical groups of data for a single season, as in 1931, are presented in Figures 58 and 59.

The green husk tissue increases in hardness as the walnut develops, usually reaching a peak during June or early July. After this time the husk softens gradually as the season progresses (Fig. 58). Females are unable to puncture the husk for egg deposition at the peak of hardness; therefore oviposition takes place on the descending slope of the seasonal husk hardness curve. Since the rate of oviposition in 1931 increased rapidly after August 20, reaching the seasonal peak about August 26 (Fig. 60), is appears that oviposition was inhibited until a hardness approximating 1,300 grams per square millimeter (Fig. 58), was reached under the conditions of these tests. (Area of needle-point was 0.2243 sq. mm.)

A brief discussion of Figure 59 is warranted. The Eureka, Franquette, Klondike, and Payne varieties are very susceptible to attack, while the Placentia variety and Seedling are notably resistant or non-susceptible. The husk hardness data given for the Eureka variety from different groves are fairly uniform, with the exception of the data for grove No. 8. This grove adjoins grove No. 1 on the south. It is of especial interest to note that irrigation is not practiced in grove No. 8, while it is an important factor in the orchard practices of most commercially-produced walnuts. The degree of infestation in grove No. 8 was very light, despite the presence of large numbers of colonized flies. In fact observations in this grove over a five-year period have shown that a consistently light infestation exists even when the infestation in the adjoining grove has on several occasions exceeded 90 per cent. The husk of the Franquette variety is shown to be appreciably harder than that of the Eureka at this time. Franquettes mature several weeks later than Eurekas and the peak of oviposition is accordingly reached several weeks later. The data given for the Placentia variety were secured from the same grove, though on different dates, as indicated. Normal harvest for the Placentia begins about September 15; therefore only a few larvae mature from the relatively small number of eggs that are deposited in the husk of this and other non-susceptible varieties.

ACCUMULATED TEMPERATURE DURING DORMANCY AND ADULT EMERGENCE.—Detailed records of adult emergence from the soil during the five-year period (involving over 37,000 flies), show that the seasonal peak varies considerably. A partial summary of these emergence data is presented in Table 1.

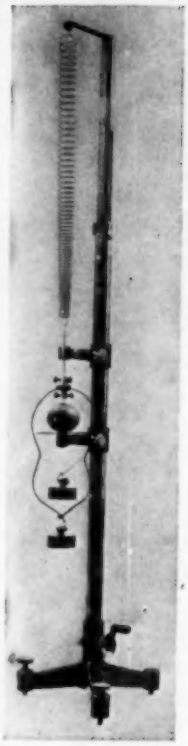


Fig. 57. — Jolly balance, modified to determine grams pressure required to puncture green husks of walnuts.

The time of adult emergence is directly dependent upon the action of factors influencing the termination of dormancy, or the diapause. A study of official weather records for the period intervening between the time that 50 per

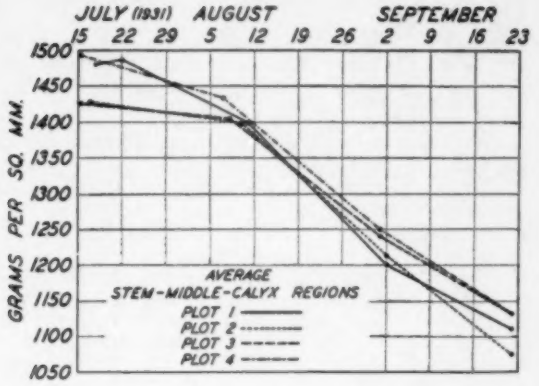


Fig. 58.—Husk hardness of Eureka walnuts during the period of *Rhagoletis completa* activity (1931). Data obtained from 4 plots in the same grove that were irrigated differently.

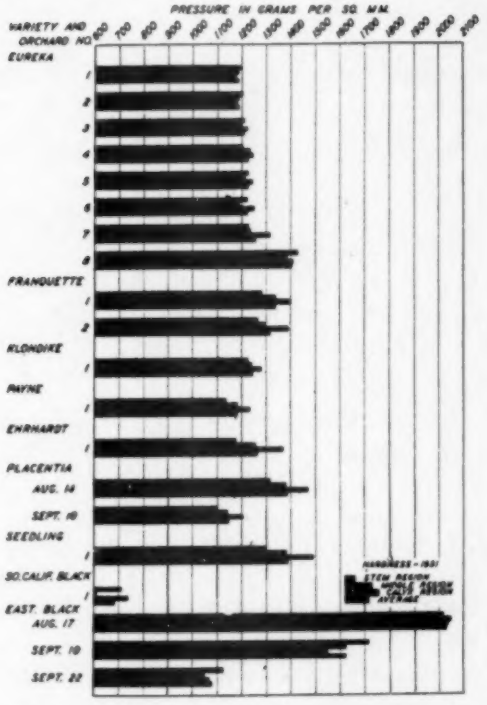


Fig. 59.—Husk hardness of various varieties of walnuts together with variation in hardness of the same variety in different groves and on different dates. Data collected August 18–22, 1931, unless otherwise indicated.

cent of the larvae entered the soil to pupate and 50 per cent of the adults emerged the following year, reveals interesting relations of temperature to dormancy. These data are summarized in Table 2, and the emergence is graphically shown in Figure 60.

TABLE 1. PARTIAL SUMMARY OF ADULT EMERGENCE DATA (*Rhagoletis completa*)

Year	Date when 50 per cent of flies had emerged	Number of flies ♀	♂	Total	Ratio ♀:♂	Approximate percentage emerged after pupae remained in soil for period of: 1 year	2 years	3 years	4 years
1928	August 17	759	700	1,459	52:48	69.9	28.6	1.21	0.24
1929	August 24	3,956	3,442	7,398	53:47	44.6	55.1—	0.33	—
1930	July 29	4,318	4,647	8,965	48:52	89.9	9.3—	0.85	—
1931	July 18	5,564	6,292	11,856	47:53	83.2	16.8—	—	—
1932	August 16	3,688	3,712	7,400	50:50	66.5	33.5	—	—
Totals and means		18,285	18,793	37,078	49:51	70.8	28.7—	0.79	0.24

The emergence curves (Fig. 60) for the years 1928, 1929, and 1932, if smoothed, may be considered normal frequency polygons, thereby indicating normalcy of emergence. However, the curves for the 1930 and 1931 seasons are materially altered in shape. The abrupt ascent and the multimodal effect probably indicate the operation of abnormal conditions upon the hibernating pupae. Temperature records show that

TABLE 2. SUMMARY OF TEMPERATURE-EMERGENCE DATA REGARDING *Rhagoletis completa*

Year	Total period annual generation individuals remain in soil: Total	Days: Departure from assumed normal	Temperature degrees F: Total day degrees	Daily mean	Monthly departure from normal
1928	321	0	19,232	59.9	+ 1.7
1929	328	+ 7	19,286	58.8	—13.8
1930	306	—15	18,313	59.8	+ 3.6
1931	291	—30	17,486	60.1	+17.4
1932	324	+ 3	18,877	59.7	— 9.0

abnormally high temperatures prevailed during the dormant period for these two years.

At the end of the 1931 season, after four years of study, it became a matter of conjecture as to whether the early emergence in 1930 and 1931 was wholly due to abnormally higher seasonal temperatures, or whether the insect was becoming synchronized with the milder climate of this state. The winter climate of the region in which it is indigenous is quite rigorous, and adults apparently emerge somewhat later in the year than has been recorded for the latest season (1929) in this subtropical region. The matter was economically important here; for, should the flies emerge during mid-June, it is probable that the green husk of all

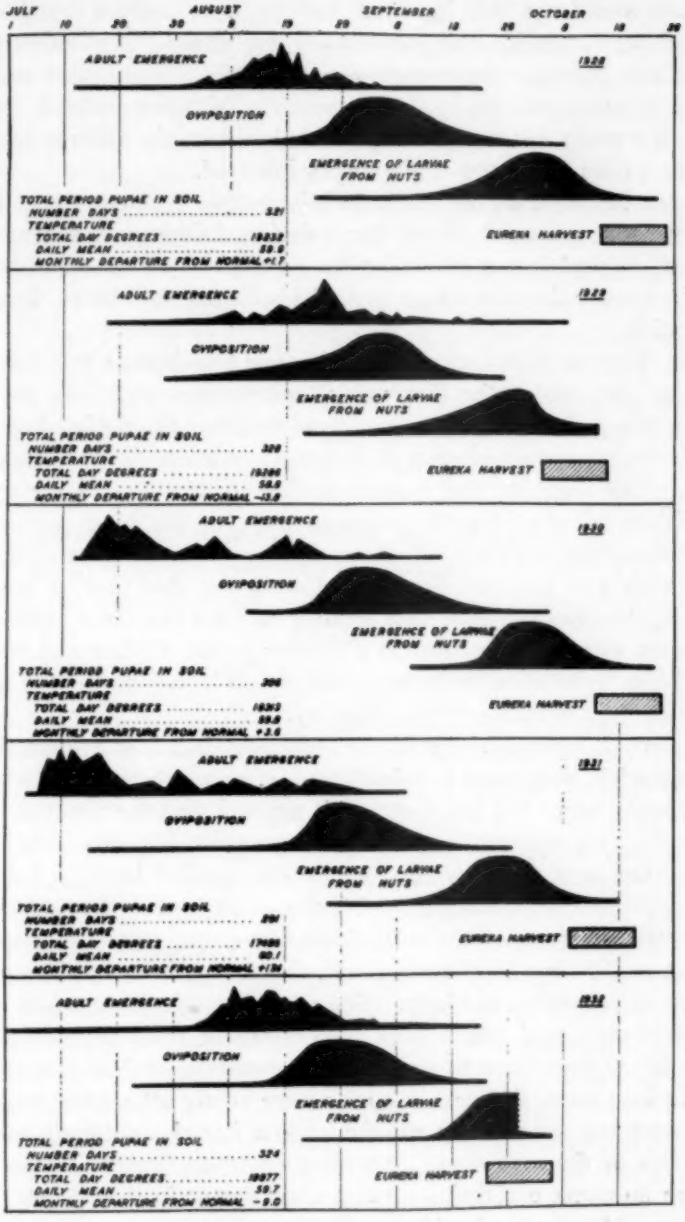


Fig. 60.—Seasonal history of *Rhagoletis completa* Cress. in the Chino-Pomona area, California (1928–1932).

varieties would not have hardened sufficiently to prevent females from ovipositing. In 1932, with subnormally low temperatures and with 355 fewer day degrees temperature than in 1928, 3 more days were required to reach the peak of emergence. This may indicate that the insect is actually becoming acclimatized; however, the differences shown may be within the range of the errors involved.

In consideration of the available information, it appears that an unknown combination of temperatures during dormancy is the most important physical factor governing the time of emergence and also, to a certain extent, the percentage of individuals that constitute the annual generation.

The 1928 and 1929 data particularly (and possibly the data for 1932) indicate that, under the fluctuating temperature conditions prevailing during the period of dormancy, transformation to adulthood was initiated when a certain amount of day degrees temperature was accumulated. This suggests that transformation to adulthood represents the completion of physiological processes that for the most part are dependent upon a combination of temperature conditions peculiar to insects with this type of diapause. Continuing this line of reasoning further, the 1930 and 1931 data possibly indicate that these physiological processes were consummated in a shorter period of time and with less actual heat units when the temperatures were higher during the warmer phase of the fluctuating temperature cycle.

Seasonal History.—From the foregoing data it is evident that the time of adult emergence is subject to factors which result in wide seasonal variations. On the contrary it appears that the time of year at which oviposition occurs remains fairly constant (Fig. 60). The peak of oviposition over the five-year period was reached beween August 25 and September 5. Moreover, with the exception of the 1929 season, the ascending slope of the oviposition curve was relatively steep; indicating, in 1930 and 1931 particularly, that an operative inhibitory factor lost its effect rather suddenly. Since the preoviposition period is from 10 to 20 days, and adults were present on the trees in great numbers for over 30 days prior to appreciable oviposition in 1930 and 1931, the conclusions seem obvious. Females were vainly attempting to oviposit and were not successful until the husk softened sufficiently to permit insertion of the ovipositor. Increased environmental resistance of this nature no doubt constitutes an important factor in the economy of the species. Moreover, should this feature of host resistance become an established fact after a few years of further observation, it would

greatly reduce the expense incident to control measures. The time for treatment would probably become a calendar date, thereby ignoring the emergence of flies for practical purposes, and one application would probably result in satisfactory control.

Another interesting feature is shown in Fig. 60. When Eureka harvest did not begin before October 10, the greater percentage of larvae had emerged prior to harvest. In 1929 the walnuts ripened early with the result that many contained immature larvae in the husk when harvested. The 1932 harvest was the earliest encountered in these studies. Very few larvae had emerged from the husks and many failed to develop. However, in most instances the larvae had developed sufficiently to cause the shell of the nut to become stained, which damage constitutes the primary type of injury. Therefore the extent of injury and resultant economic loss were not materially mitigated.

CONTROL OF THE WALNUT HUSK FLY, *RHAGOLETIS COMPLETA* CRESS.[1]

By A. M. Boyce, *University of California Citrus Experiment Station*

Abstract

Results of laboratory and field experiments regarding control of the walnut husk fly, *Rhagoletis completa*, show that synthetic cryolite and barium fluosilicate were the most satisfactory of the materials tested, which included certain arsenical, fluorine, nicotine, and copper compounds. A table is presented which summarizes the more important data pertaining to a few typical plot experiments conducted during the period 1928–1932.

The Persian walnut (*Juglans regia*) industry of the United States is centered in the state of California, where approximately 97 per cent of the domestic tonnage is produced. There are over 100,000 acres of walnut trees in bearing at the present time. The recorded insect fauna of the genus *Juglans* numbers over 300 species, of which relatively few occur in this state. Before the advent of the trypetid, *Rhagoletis completa*, the only species considered to be of major importance to the industry were the codling moth, *Carpocapsa pomonella* (Linn.), and the walnut aphid, *Chromaphis juglandicola* (Kalt.).

The walnut husk fly, *Rhagoletis completa*, was introduced into California prior to 1926, probably as larvae or pupae in black walnuts (*Juglans* sp.) from the central region of the United States (about the 100th meridian), where it is undoubtedly indigenous. In 1927 the species

[1]Paper No. 277, University of California Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

assumed major economic importance as a pest of certain commercial varieties of Persian walnut. The area of infestation has increased yearly and in 1932 it comprised approximately 500 square miles and included over 2,000 acres of commercial walnut groves.

In 1928 a study of the biology and economics of this insect was begun. These investigations were continued each succeeding year and have been fairly extensive. The problem was "rounded out" in 1932 and a manuscript covering the entire project was prepared for a technical publication. It is the purpose of this paper to "sum up" the more important information obtained regarding the control of this species. The major portion of the work dealt with a determination of the relative merits of the more promising available toxic materials for destroying the adults under laboratory and field conditions, and also with a determination of the effect of these materials on the walnut trees.

LABORATORY TOXICOLOGICAL INVESTIGATIONS AND FIELD STUDIES OF TREE TOLERANCE.—The following materials and combinations have been employed in toxicity tests in the laboratory and in field studies of tree tolerance: acid lead arsenate, basic lead arsenate, calcium arsenate, magnesium arsenate, manganese arsenate, sodium arsenite, barium fluoride, barium fluosilicate, calcium fluoride, calcium fluosilicate compound, magnesium fluosilicate, potassium fluoaluminate, sodium fluoride, sodium fluosilicate, sodium fluoaluminate (cryolite, synthetic), sodium fluoaluminate (natural), copper sulfate, copper carbonate, nicotine sulfate-bentonite, nicotine sulfate-butanol-mineral oil, nicotine sulfate-diatomaceous earth, nicotine sulfate-sucrose, nicotine tannate, ground tobacco leaves, bentonite, calcium hydroxide, diatomaceous earth, sulfur, and fiber talc. The results obtained from the toxicity studies in 1929,[2] 1930,[3] and 1931,[3] have already been published. The data secured in 1932 are presented in Figure 61.

A total of 279 individual toxicity experiments comprising 8,975 flies were conducted during this 4-year period. A brief summary of the more important results follows.

Of the arsenicals tested, basic lead arsenate was consistently slowest in speed of lethal action, though aside from magnesium arsenate it was

[2]Boyce, A. M. Effectiveness of certain materials in producing mortality of the walnut husk fly, *Rhagoletis completa* Cress. California Dept. Agr. Mo. Bul. Vol. 20, pp. 682–690. 1931.

[3]Boyce, A. M. Mortality of *Rhagoletis completa* Cress. (Diptera: Trypetidae) through ingestion of certain solid materials. Jour. Econ. Ent. Vol. 25, No. 5, pp. 1053–1059. 1932.

the only one of the group that did not cause foliage injury. With respect to magnesium arsenate one season's observations indicated that it is safe to use on walnut foliage; however, its lethal action apparently was not appreciably more rapid than that of basic lead arsenate. Of the fluorines tested sodium fluoaluminate (cryolite, synthetic), barium fluo-

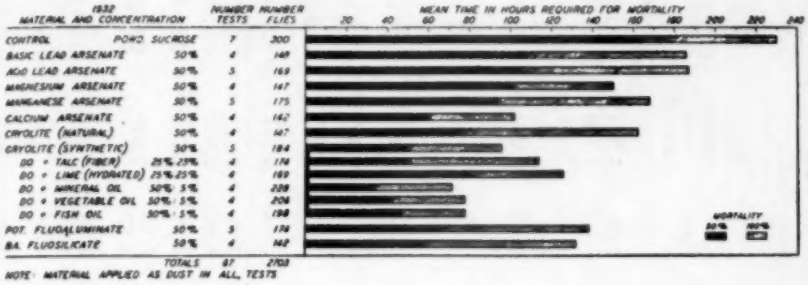

1932
MATERIAL AND CONCENTRATION
NUMBER TESTS
NUMBER FLIES
MEAN TIME IN HOURS REQUIRED FOR MORTALITY
20 40 60 80 100 120 140 160 180 200 220 240
CONTROL POHO SUCROSE 7 300
BASIC LEAD ARSENATE 50% 4 149
ACID LEAD ARSENATE 50% 5 169
MAGNESIUM ARSENATE 50% 4 147
MANGANESE ARSENATE 50% 5 175
CALCIUM ARSENATE 50% 4 162
CRYOLITE (NATURAL) 50% 4 147
CRYOLITE (SYNTHETIC) 50% 5 184
DO + TALC (FIBER) 25% 25% 4 174
DO + LIME (HYDRATED) 25% 25% 4 189
DO + MINERAL OIL 50% 5% 4 208
DO + VEGETABLE OIL 50% 5% 4 206
DO + FISH OIL 50% 5% 4 198
POT. FLUOALUMINATE 50% 5 174
BA. FLUOSILICATE 50% 4 142
MORTALITY
50% 100%
TOTALS 67 2703
NOTE: MATERIAL APPLIED AS DUST IN ALL TESTS

Fig. 61.—Results of toxicity studies in 1932 (*Rhagoletis completa* Cress.).

silicate, and potassium fluoaluminate were the most promising from the point of view of toxicity to the insect and tree tolerance. The copper compounds tested offered promise with respect to lethal action though they were deleterious to walnut foliage. The nicotine compounds and combinations tested were effective as stomach poisons on the flies though they were not as practicable in the field as the several fluorines mentioned. Of the inert diluents, either diatomaceous earth or talc was satisfactory. Hydrated lime employed as a diluent with sodium fluoaluminate materially retarded lethal action. All diluent materials tested, whether chemically active or inert, were lethal to the flies. The incorporation of either mineral oil, vegetable oil, or fish oil, at a concentration of 5 per cent, for adhesive purposes, did not retard lethal action of the insecticide dust mixture. However, at a concentration of 12 per cent both mineral oil and fish oil apparently inhibited the speed of fatality.

Field Control Investigations.—Field-plot control experiments were conducted each season from 1928 to 1932 inclusive. A total of 140 individual plot experiments comprising approximately 300 acres of walnuts were conducted during this 5-year period. A brief summary of the more important data regarding several typical experiments each season is presented in Table 1.

Very erratic results were obtained from the use of basic lead arsenate in 1928 and 1929 as spray and as dust, with nearly full coverage, and also as bait treatments. No doubt variations in host resistance in the nature of hardness of the green walnut husk, and insufficient size and

TABLE 1. SUMMARY OF THE MORE IMPORTANT DATA REGARDING A FEW TYPICAL PLOT EXPERIMENTS IN FIELD CONTROL STUDIES (1928–1932) OF THE WALNUT HUSK FLY, *Rhagoletis completa* CRESS

Year and peak of adult emergence	Material and concentration	Application: Method	Application: Amount per tree	Application: Number	Application: Date	Results: Total number nuts counted	Results: Mean per cent infested	Results: Per cent control
1928 Peak of emergence Aug. 17	Basic lead arsenate 4 lbs.—100 gal.	Spray	20 gal.	1	8/2	1,334	25.0	64.8
	Check—No treatment	——	——	—	——	1,480	71.0	——
1929 Peak of emergence Aug. 24	Basic lead arsenate 4 lbs.—100 gal.	Spray	20 gal.	3	8/2 8/19 9/3	1,000	11.4	57.8
	Basic lead arsenate 6 lbs. + N. O. molasses 5 gal. + Cane sugar 25 lbs. — 100 gal.	Spray	5 gal.	"	"	1,139	13.9	48.6
	Check—No treatment	——	——	—	——	934	27.0	——
	Basic lead arsenate 16 lbs. + Corn sugar 25 lbs. — 100 gal.	Spray	3 gal.	3	8/3 8/17 9/4	2,307	6.8	74.9
	Basic lead arsenate 100%	Dust	1¼ lbs.	"	"	2,531	3.5	87.1
	Check—No treatment	——	——	—	——	2,114	27.0	——
1930 Peak of emergence July 29	Basic lead arsenate 4 lbs.—100 gal.	Spray	15 gal.	1	7/16	2,141	6.2±1.0	——
	"	"	"	1	8/12	2,160	3.8±0.8	——
	Basic lead arsenate 20 lbs. + Hydrated lime 80 lbs.	Dust	3 lbs.	1	7/16	2,152	12.2±3.7	——
	"	"	"	2	7/16 8/13	2,209	6.4±1.4	——
	Barium fluosilicate 20 lbs. + Talc 80 lbs.	Dust	2 lbs.	2	7/18 8/13	4,154	0.9±0.2	89.2±0.2
	Basic lead arsenate 20 lbs. + Hydrated lime 80 lbs.	Dust	2 lbs.	"	"	449	36.7±6.6	+95.8±1.3††
	Check—No treatment	——	——	—	——	2,621	8.3±1.9	

	Check—No treatment	——	——	—	——	2,621	8.3±1.9	

	[Barium fluosilicate 20 lbs. Talc 80 lbs.]	Dust	2 lbs.	1	7/9	4,182	16.9±1.0	45.0±4.5
	"	"	"	2	7/9 8/17	7,299	2.7±0.2	91.2±4.5
1931	Barium fluosilicate 3 lbs.—100 gal.*	Spray	15 gal.	1	7/14	9,952	6.2±0.4	79.8±4.5
Peak of	" †	"	"	"	"	8,237	17.1±1.1	44.3±4.5
emergence	Check—No treatment	——	——	—	——	6,924	30.7±1.8	——
July 18	[Cryolite (Synthetic) 20 lbs. Talc 80 lbs.]	Dust	3 lbs.	1	7/13	2,954	8.5±1.5	62.4±9.7
	[Cryolite (Natural) 20 lbs. Talc 80 lbs.]	Dust	3 lbs.	2	7/13 8/17	2,165	3.5±0.5	84.5±6.2
	Check—No treatment	——	——	—	——	2,513	22.6±3.2	——
	[Nicotine sulfate (40%) 1 pint Tannic acid 3 lbs.] 100 gal.	Spray	15 gal.	2	7/13 8/5	2,586	13.2±1.8	74.4±5.3
	Barium fluosilicate 3 lbs.—100 gal.	"	"	"	"	2,082	8.2±2.6	84.1±6.1
	Check—No treatment	——	——	—	——	2,693	51.4±8.8	——
	[Cryolite (Synthetic) 20 lbs. Talc (Fiber) 75 lbs. Mineral oil 5 lbs.]	Dust	3 lbs.	2	7/29 8/31	4,167	0.6±0.2	97.3
	"‡	"	"	"	"	6,686	9.2±1.4	57.8
1932	[Potassium fluoaluminate 20 lbs. Talc (Fiber) 75 lbs. Mineral oil 5 lbs.]	"	"	"	"	4,627	0.5±0.2	97.9
Peak of emergence August 16	Check—No treatment	——	——	—	——	435	21.8	
					7/28	7,800§	22.6±2.2	
	[Cryolite (Synthetic) 30 lbs. Diatomaceous earth 65 lbs. Mineral oil 5 lbs.]	Dust	3 lbs.	2	8/28	7,893‖	7.5±0.9	
						7,782¶	5.9±0.4	
						3,516**	20.9±1.6	
	Check—Untreated isolated susceptible trees in adjoining groves of non-susceptible varieties.	——	——	—	——	1,288	57.2±11.5	——

*Peach interplants treated.
†Peach interplants not treated
‡Border row adjacent to non-susceptible varieties that were not treated.
§West border row. Adjacent west row untreated.
‖Row adjacent to and east of row 1, only 50 feet distant.
¶From major portion of center of grove.
**East border row. Adjacent east row untreated.
††Actual increase in degree of infestation over check.

isolation of plots were contributory factors. Accordingly, during the last 3 years of the study great care was taken to select plots of adequate size, and individual plots were isolated as fully as practicable. Usually four rows of trees that were thoroughly sprayed separated the plots from each other within a grove. Also a bordering zone of non-susceptible varieties was treated. In this manner the general migration of flies from plot to plot was apparently precluded. Furthermore when materials were applied as dusts the "drift" into nearby plots was reduced to a minimum. The data regarding degree of infestation were always taken from the central portions of the plots.

The role of sweet materials in control practices received considerable attention. Chemotropic studies showed that sucrose was not an attrahent for the flies; however when applied to the foliage it served to congregate them during their normal feeding migration about the tree. The period over which both sucrose and New Orleans molasses were palatable to the flies was in direct proportion to the concentration used. At concentrations of 5 and 10 per cent, this period was several days. However, since foliage injury resulted at these concentrations, bait treatments are not particularly promising in the control of this fly.

Barium fluosilicate and synthetic cryolite were more efficacious than basic lead arsenate; consequently they were fairly extensively tested during the latter portion of this study. Their adhesive qualities were low; however, the incorporation of fish oil, vegetable oil, or mineral oil rendered them satisfactory in this respect. Mineral oil was found most desirable for this purpose.

Both fiber talc and diatomaceous earth served as satisfactory diluents for these fluorine compounds when applied as dust. Each material possessed certain qualities superior to the other. Fiber talc was found to be superior to granular talc, and diatomaceous earth from fresh water deposits was superior to that from marine deposits. A specific advantage of diatomaceous earth is that it is very light and bulky and the incorporation of oil for adhesive purposes does not affect its dusting qualities. Furthermore where relatively small amounts (3 to 4 pounds) are applied per tree the operator is more likely to distribute the material thoroughly over all parts of the tree than when applying a heavier material. A bulky material may be disadvantageous in that mixing costs and costs of application are slightly increased; however, the factors already mentioned appear to counteract the disadvantages.

Proper mixing of the ingredient materials is very essential. Series of mixing tests were conducted in a specially designed dust-mixing

plant to determine the minimum time necessary to obtain a satisfactory mixture. These tests showed that 5 minutes continuous agitation of the toxic element (cryolite) with the diluent (earth) was necessary before the oil was atomized into the hopper containing the mixture. Then agitation for 10 minutes longer was required to distribute the oil properly throughout the dust mixture.

Based on the data obtained from field control plots and from general observations on hundreds of acres of commercially treated walnut groves in the infested area, the following conclusions appear to be warranted. Satisfactory control of the walnut husk fly may be obtained through the use of synthetic cryolite (97 + per cent sodium fluoaluminate) or barium fluosilicate. As a spray, the recommended formula is:

Cryolite (synthetic) or barium fluosilicate.....3 pounds
Mineral oil (95 seconds viscosity, 90% unsulfonatable)....1 quart
Water ..... 100 gallons

From 30 to 40 gallons per average sized walnut tree affords satisfactory coverage. The economics of the problem favor the dust method of treatment. The recommeded formula is (by weight):

Cryolite (synthetic) or barium fluosilicate.....30 per cent
Diatomaceous earth .....65 per cent
Mineral oil (95 seconds viscosity, 90% unsulfonatable)..5 per cent

From 3 to 4 pounds per average sized tree affords satisfactory coverage.

To insure adequate protection within a grove through insecticidal treatment, a zone of adjacent vegetation from 50 to 100 feet wide must be treated simultaneously with the infested grove. In view of the limited duration of experimental work with these materials, two treatments are recommended; the first when adult emergence becomes regular, and the second approximately four weeks following the first.

OBSERVATIONS ON THE HABITS OF FLIES BELONGING TO THE GENUS *RHAGOLETIS*[1]

By M. G. FARLEMAN, *Department of Entomology, Michigan State College*

ABSTRACT

Field observations show that cherry fruit flies appear on the trees earlier than in cages. *R. fausta* is the first species to appear, followed directly by *R. cingulata* and *R. pomonella* three or four weeks later. Influence of light, temperature, moisture, ripeness of fruit, and wild hosts are discussed.

It happens that in the control of both the cherry fruit flies and the apple maggot it is necessary to time accurately the sprays so that they

[1]Journal Article No. 136 (n. s.) from the Mich. Agr. Exp. Sta.

will be applied at a definite period after the first appearance of the adults. At first cages were used, but as time went on it became apparent that we were capturing flies from one to five days earlier by a system of field scouting than through the agency of cages. The use of cages has, therefore, been discontinued and data taken directly from the orchards. The present paper deals with three species: *Rhagoletis cingulata*, on cherry, both sour and sweet; *R. fausta* on cherry, for the most part on sour cherry; and *R. pomonella* on apple. Of these *R. fausta* appears first of all, closely followed by *R. cingulata*. *R. pomonella* appears from three to four weeks later than the cherry fruit flies. The emergence in the case of any one species takes place first in the lower tier of counties and then a wave of emergence gradually progresses northward as the season advances. In 1932 the first emergence of cherry fruit fly took place in Van Buren county on June 7th. The last emergence occurred in Leelanau county on June 14th and at intermediate points the flies appeared in regular order.

Members of this genus pass the winter as pupae in the ground, from which they emerge from June until September. It would be expected that by sweeping the grass of infested areas about emergence-time many specimens resting on the vegetation just above the ground could be taken. Intensive search during three summers in infested locations, however, has yielded but a few specimens from grass sweepings. The flies caught in such places have been taken in both long and short grass, but on some occasions fruit flies seemed to occur in deep grass as a result of their apparent liking for partial shade, although their occurrence after storms may result from their having sought shelter in such places. Sweepings of surface vegetation in cultivated orchards has been uniformly unproductive.

More flies have been caught early in the day and after rain and wind storms than at other times, and though it is probable that occurrence after a rain is correlated with facilitation of movement through the soil, by the softening influence of moisture, the general impression gained from the three seasons' collections is that fruit flies are more readily found when comparatively warm, moist conditions prevail. It is possible also that light conditions in the morning and after storms effect photo-tropic responses which enter somewhat into a determination of the time when fruit flies are observed, for few have been caught except in mingled light and shadow, such as occurs among the leaves on the sunny side of the tree. Further support of this surmise can be drawn from the fact that more fruit flies have been caught on the upper sides

of the leaves on dull days, whereas the opposite condition has obtained on bright days.

Greater numbers of fruit flies have been caught on the middle third of the brighter side than on any other parts of the trees observed. Greater numbers of *R. cingulata* have been caught from the upper half of the tree, while *R. fausta* and *pomonella* are more commonly found on the lower half of the tree. Specimens have never been found resting upon the bark of trees, nor on the smaller twigs. Always they have been found either on the foliage or on the fruit. The greater percentage of the specimens are found on the leaves, but that is natural to expect, since there are greater numbers of leaves than fruit. Where apple and cherry trees are inter-planted, specimens of *R. fausta* have been numerous on cherry and have confined themselves entirely to that plant. Later in the same season this has also been true of *R. pomonella.* Even though the trees were planted closely together, *R. pomonella* has never been collected except on apple, save for one specimen on Montmorency cherry near East Jordan in Charlevoix county late in July of 1931.

As has before been noted, there is an apparent relation between light intensity and the appearance of flies upon the upper or the lower surfaces of leaves. This condition, coupled with alternating dark and light areas upon the wings and with the effect of sunshine through leaves, makes flies of this genus hard to see, despite their characteristic attitude of rest. When disturbed, fruit flies take short, rapid, curved flights, which usually end upon the underside of a leaf. As nearly as can be judged from observation, speed of flight is greatest in *cingulata*, next in *fausta*, and slowest in *pomonella.* Flies of the genus *Rhagoletis* are usually hard to catch, although their capture is somewhat influenced by extremely warm, muggy weather. Under such conditions sixty specimens of *R. fausta* were caught directly into a cyanide bottle from Montmorency cherry trees at one time. Usually, skillful use of an insect net is necessary in the capture of fruit flies. The type of flight and the common habitat among the leaves unite to make sweeping the leaves and branches inadvisable. Another objection to this practice in the early season or where flies are scarce is that the flies readily take flight ahead of the sweeping.

It has been thought that both species of *Rhagoletis* attacking cherry begin ovipositing just as soon as the fruit acquires a little color, after passing through a short period devoted to feeding and mating after emergence. Numbers of *Rhagoletis fausta* were repeatedly observed the first week in June, 1932, trying to oviposit on Montmorency cherries

two or three weeks prior to picking, while the fruits were green and hard. This seems to indicate that before oviposition can be successful, the fruit must be soft enough in texture to allow the insertion of the ovipositor.

Efficient control may be somewhat lessened by infestation from certain wild host-plants that are numerous and particularly adapted to Michigan conditions. *R. fausta* and *cingulata* breed readily in the following: Wild black cherry (*Prunus serotina*), choke cherry (*P. virginiana*), pin cherry (*P. pennsylvanica*), and mahaleb cherry (*P. mahaleb*, escaped from cultivation). *R. pomonella* breeds successfully in hawthorn (*Crataegus*).

A PRACTICAL METHOD OF CONTROLLING *DENDROCTONUS VALENS* LEC.

By Eric Walther, *Golden Gate Park*[1]

Abstract

A method of injecting carbontetrachloride is described and the results given.

In common with most other pine-forests of California, the plantations of Golden Gate Park also have suffered from the depredations of bark-beetles, of which *Dendroctonus valens* Lec. must be considered the most dangerous one, by reason of its more primary nature. The relatively high value of individual trees led to an attempt at their treatment, a summary of which is presented here as possibly of wider interest and value.

The idea of killing bark-beetles within their burrows is by no means new; and the utilization of toxic vapors to control boring insects also is well known, as in the case of the peach-tree borer, control of which last with Paradichlorbenzene has become standard practice. As far as the present writer is aware, though, this is the first instance where sufficiently large numbers of pines attacked by *Dendroctonus valens* were actually saved to permit of any sound conclusions as to the practicability of the method and materials used.

Out of a total of about 8,500 Monterey pines around 1,400, or 17%, were attacked by the above beetle during the past 2 seasons, of which number fully 1,200 were successfully treated. These show no injury from the effect of the treatment, and evidence of healing-over of beetle-damaged areas. The number of pines cut as not worth saving amounts to less than the normal annual cut under a rotation of 40 years.

The method finally adopted consists, essentially, of the injection into the beetle-burrows, of Ethylene-dichloride.

[1]Published with permission of John McLaren, Park Superintendent.

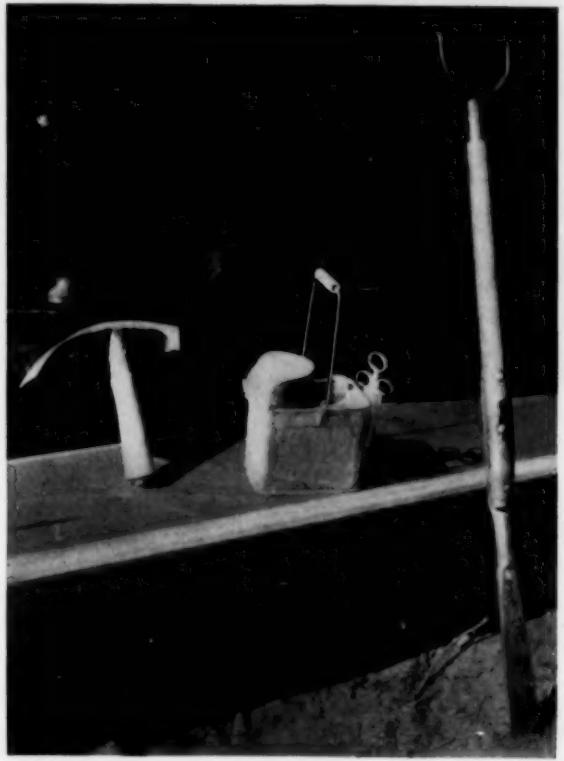
Plate 35

A dying pine infested with
both mite and beetle

A healthy mountain pine

Injecting burrow

Treated burrow



Tools used

This relatively new product is quite similar in action to carbon-bisulphid and carbontetrachloride, but combines the volatility and consequent toxicity of the former with the safety and non-offensive odor of the latter. In practice it was found impossible to inject the liquid through the entrance-holes as found, since the resin very soon effectively clogged up the nozzle of the syringe. It was found advantageous to cut away the outer bark, and the best tool for the purpose turned out to be a cooper's adze, with a rather sharply curved, well-balanced cutting-blade. The outer bark of old Monterey pines is so deeply fissured at the base that it is almost impossible to close all cracks and openings unless this dead bark is trimmed away. Incidentally this serves to mark the trees treated, serving to facilitate rechecking. Injection of the liquid is by means of a common medical syringe holding about one ounce, equipped with a special tip having a broad shoulder and a tip smaller than the beetle-burrow, so that with a little pressure a tight fit against leakage while injecting may be attained. After injection of as much poison as the particular burrow will hold, all openings, cracks, etc., are plugged with putty, so that the resultant vapor is confined as long as possible and given a fair chance to penetrate to all parts of the larval chamber. The area treated is gone over again within 3 weeks or so, when active burrows can readily be spotted by the extruded pitch-tubes or saw dust, and retreated. Efficiency of this method ran very high, often exceeding 95%, dropping below this only on *Pinus pinaster* and badly infested trees. The reduction in results may be explained by the more elongated, narrower burrows of the beetles where they are crowded. Normally the larval chamber of *D. valens* is only slightly longer than broad, permitting the poison-gas to readily reach all larvae, pupae and beetles. It is in any case advisable to commence control-work as early as possible, to avoid serious injury, and to so time the work as to meet the peak of beetle-activity. While no exact statements are possible, locally at least the relative number of active burrows found would seem to indicate the presence here of at least two generations a year, with the spring-brood the larger one. Little activity is noticeable during the cold winter-months, and the peak of activity is reached during May and April, with a second, smaller brood in September.

Of natural enemies the only one noted in numbers sufficient to render it of importance was a predacious mite, apparently of the genus *Parasitus*, nymphs of which were often extremely abundant both on larvae, pupae and adult beetles.

Tools used

Treated burrow

Injecting burrow

While *Dendroctonus valens* is essentially much more primary than most other bark-beetles, it should be recorded that the pines of the Park, throughout most of its 1,013 acres, were seriously weakened through the lowering of the local watertable consequent upon several dry winters, as well as from the effect of a long-standing infestation of the pine-needle-mite, *Eriophyes pini* Nalepa.[2]

In the course of our operations it was found that here, as elsewhere, the most prolific source of beetles were stumps and felled trees, a complete cleanup of which of course should precede any other work. In a number of cases stumps were found with beetles so nearly mature as to make impossible their removal. These were carefully exposed by digging, and then burned in situ by using fuel-oil fed beneath the stump through a length of pipe from an oil-drum.

The cost of the treatments depends on several factors, as severity of infestation, labor-costs, value of the trees, etc., but in the present case did not exceed $0.25 per tree per treatment. The success of the method outlined depends primarily upon its adaptation to the particular insect concerned, its habits and life-history; and it by no means follows that all bark-beetles may be dealt with in the same manner. Likewise the old recommendations still hold good as to sanitation, reforestation, etc., into which we can not and need not go any further here.

In closing we submit 3 tables which are self-explanatory, and assure all interested that any further information desired shall be gladly furnished on request.

TABLE 1. NUMBER OF ACTIVE BURROWS TREATED DURING EACH MONTH

1931—July	662	11%
August	1302	22%
September	*683*	11%
October	328	5%
November	241	4%
December	79	1%
1932—January	115	2%
February	100	2%
March	220	4%
April	783	13%
May	797	13%
June	596	10%
(12 months total	*5906*	100%)
1932—July[1]	476	8%
August	574	9%
September	430	

Active burrows treated during June 1933=104.

Total burrows treated July 1931 to July 1933=18,724.

[1]The first two months of the new fiscal year the reduction in numbers of the beetles amounts to over 46% compared to the year before.

[2]See "Journal of Economic Entomology;" 1925: 830, and 1928: 628.

TABLE 2. EFFECT OF CARBON-TETRA-CHLORIDE ON VARIOUS STAGES OF *Dendroctonus valens* LEC.

A. Nearly mature larvae	Died after 90 minutes
B. Old beetles	150 "
C. Pupae	250 "
D. Young beetles	300 "
E. Checks of all stages	(all alive)

Condition of test—Equal numbers of the various stages were exposed to the fumes only of the gas, 5 ccm. of C.T.C. were placed in a large test-tube corked at the top, inside of which was a smaller tube containing the insects, and communicating with the outer tube by the open top only. For the purpose of this test death was supposed to have occurred when no motion whatever was perceptible after shaking.

TABLE 3. TIME REQUIRED BY VARIOUS CHEMICALS TO PRODUCE APPARANT DEATH

A. Carbon bisulphide	All motion ceased after 15 min.
B. Ethylene dichloride	90 "
C. Carbontetrachloride	300 "
D. Paradichlorbenzene	(All alive)
E. Checks	(All alive)

Condition of test—Same as under No. 2; temp. 65 deg. F.; young beetles only used.

DISTRIBUTION OF MAY-BEETLES (*PHYLLOPHAGA*) IN MICHIGAN[1]

By W. F. MOROFSKY, *Department of Entomology, Michigan State College*

ABSTRACT

A study of the distribution of the May-beetles of Michigan in which are discussed the occurrence and range of the sixteen species which are known at present to inhabit Michigan.

The present study was begun in 1927 for the purpose of determining the species and distribution of May-beetles in Michigan. Specimens were collected from forty-one counties, being sent in from different localities by students, county agents, and farmers with inquiries as to their control. As the beetles were received the genitalia were removed, date recorded, and later they were identified. By this means a very good representation of both species and distribution was acquired. Collections were made by the writer throughout the entire period of flight, during 1930, 1931 and 1932. A total of 11,000 adult Phyllophaga were collected and studied. In addition to this the writer has had access to the Michigan State College collection, which dates back to 1874.

Of the forty-one counties from which collections were obtained, eight species were recorded in the northern, fourteen species in the central, and nineteen species in the southern counties.. The writer is led to believe that weather conditions, especially rainfall, play a large part in the distribution of the species.

[1]Journal Article No. 137 (n. s.) from the Mich. Agr. Exp. Sta.

MAY-BEETLES OF THE THREE SECTIONS OF THE STATE IN ORDER OF ABUNDANCE

Northern Michigan

Phyllophaga anxia
Phyllophaga drakii
Phyllophaga marginalis
Phyllophaga grandis

Central Michigan

Phyllophaga rugosa
Phyllophaga hirticula
Phyllophaga anxia
Phyllophaga futilis
Phyllophaga fusca
Phyllophaga crenulata
Phyllophaga tristis
Phyllophaga drakii

Southern Michigan

Phyllophaga rugosa
Phyllophaga hirticula
Phyllophaga anxia
Phyllophaga fusca
Phyllophaga futilis
Phyllophaga crenulata
Phyllophaga tristis
Phyllophaga ilicis
Phyllophaga inversa
Phyllophaga ciliata
Phyllophaga dubia
Phyllophaga gracilis
Phyllophaga gibbosa
Phyllophaga pruniana
Phyllophaga longispina
Phyllophaga balia
Phyllophaga lugubris
Phyllophaga grandis

The total number of species recorded in Michigan from 1874 to 1932, inclusive, is twenty-one, of which five are synonyms. The number of specimens collected varied from 7,213 of *P. rugosa* to four of *P. marginalis*. According to the numbers of specimens collected and identified, *P. rugosa* amounted to eighty per cent, with *P. hirticula* and *P. anxia* next. Following are listed seven species which include ninety-five per cent of all specimens collected.

IMPORTANT SPECIES IN MICHIGAN ACCORDING TO NUMBERS

Phyllophaga rugosa	7,213	*Phyllophaga fusca*	419
Phyllophaga hirticula	963	*Phyllophaga tristis*	298
Phyllophaga anxia	649	*Phyllophaga crenulata*	60
Phyllophaga futilis	468		
Total			10,070

Most of the May-beetles collected were taken at or near electric lights at different times and dates; no special traps were used. This holds true with the exception of species such as *futilis, tristis,* and *crenulata. Futilis* was commonly found under raspberry plants, although it has never been found feeding. *Tristis* and *crenulata* were found early in the spring, commonly under rose. Although no special efforts were made to find host-plants of species, the writer did observe them when possible.

Of the 10,000 May-beetles collected at or near electric lights, approximately eighty-nine per cent were found to be males in all species, except in the case of *P. anxia,* which showed more females than males in all localities collected.

In the following summaries of Michigan May-beetles, an attempt will be made to discuss the seven most important species of the state as to numbers collected, dates, and where found.

Phyllophaga rugosa (Melsh.) was found to be the most abundant

species in the state. Of the 11,000 beetles collected, 7,213 specimens were *rugosa*. The range of this species was found to occupy the southeastern third of the state, extending from Berrien County across to Bay County, including the entire Thumb District of Michigan. The first beetles were collected on May 20th and the last on July 7th. All of the beetles collected were taken at electric lights and, therefore, not checked as to food plants, but there is no doubt but that *rugosa* is one of our most destructive species, especially in the larval stages. According to Forbes in his "Illinois May-Beetles", the adult *rugosa* confines itself mostly to poplars and elms.

Phyllophaga hirticula (Knoch.) was first described by Knoch in 1801 and is found to be more or less common throughout the southeastern United States. It ranks second in abundance in Michigan. Of the 963 specimens taken, forty per cent were collected at electric lights. The sixty per cent collected by the writer were found to be feeding on oak, hickory, elm, ash and black cherry, of which oak was first choice.

Hirticula did not range as far north as *rugosa*. It was found in fourteen counties of southwestern Michigan, as compared with *rugosa*, which was found in twenty-three southeastern counties. The most northern county for *hirticula* was Kent County. It has attracted more attention than other species, as several wood-lots in southwestern Michigan have been completely defoliated by the adults. There would appear to be an overlapping of broods, causing a complete defoliation for the past two years, 1930 and 1931. With the aid of *anxia* in 1932, several wood-lots, which had previously been defoliated by *hirticula*, were again defoliated, causing the death of several stands of oaks. The first beetles of *hirticula* appeared on May 20th and the last on July 1st.

Phyllophaga anxia (Lec.) is the most wide-spread of all our Michigan May-beetles and also is our most northern species. It was formerly known as *dubia* and ranges over the entire state, being reported from twenty counties in the lower and from two counties in the upper peninsula, Chippewa and Gogebic, but not in great numbers. Five-hundred and fifty-nine specimens were taken at or near electric lights, while ninety were collected by the writer at night, feeding on oak. This species does not seem to be of economic importance in the lower peninsula. It was collected from May 1st to June 28th. Of the 559 specimens taken at electric lights, approximately seveny-five per cent were found to be females.

Phyllophaga futilis (Lec.) is more or less restricted to the lower southeastern counties in Michigan, and is not of great economic importance. It is found in six counties, Monroe, Lewanee, Washtenaw, Wayne, Liv-

ingston, and Ingham. Three hundred specimens were taken at electric lights from May 20th to June 25th, and 168 adults were collected by the writer during the daytime under raspberry plants in Monroe and Ingham counties, although no injury was found on the raspberry plants.

Phyllophaga fusca (Froel.) is more or less common throughout central Michigan. Four hundred nineteen specimens were taken at electric lights in six counties from April 18th to July 1st.

Phyllophaga tristis (Fab.) is of little importance throughout the south and central portion of the state. It was taken in eight counties. Two-hundred and two specimens were collected near electric lights and ninety-six were collected by the writer just at dusk coming from under rose bushes which were completely surrounded by sod. *Tristis* was always found to be local and its distribution never widespread. Collected from May 5th to June 25th.

Phyllophaga crenulata (Froelich) is represented by sixty specimens taken in four counties centrally located from May 9th to June 23rd.

The foregoing accounts for Michigan's first seven species of May-beetles in order of abundance. Following are listed the sixteen species of May-beetles with synonymy[3] indicated:

rugosa
anxia = dubia
crenulata
tristis
hirticula
fusca
ilicis = ciliata
futilis = gibbosa
drakii = grandis
forsteri = lugubris
marginalis
inversa
gracilis
pruniana
longispina
balia

This list includes all of the Michigan May-beetles up to this date. The numbers vary greatly in abundance from 7,213 *rugosa* to four *marginalis*, ninety-five per cent of which belong to the seven main species. The rest are distributed among the remaining nine species. It is found that four species of May-beetles inhabit northern Michigan. Eight are restricted to the central, and eighteen are found in the southern portion.

The writer wishes at this time to acknowledge the aid received from A. F. Satterthwait in checking determinations, from E. I. McDaniel in preparation of specimens, from Ray Hutson for criticism of the manuscript, from students who aided in collecting material, and from Dr. R. H. Pettit, Head of the Section of Entomology, for facilities in making the study possible, in addition to suggestion, encouragement and criticism of the manuscript.

[3]The nomenclature of this list is that of Dr. Robert D. Glasgow, as given in Article V, Vol. XI, of the Bulletin of the Illinois State Laboratory of Natural History.

SPRAYING TO CONTROL THE GLADIOLUS THRIPS, *TAENIOTHRIPS GLADIOLI* M. & S., IN MICHIGAN FOR THE SEASON OF 1932[1]

By E. I. McDANIEL, *Department of Entomology, Michigan State College*

ABSTRACT

Contact sprays including lead arsenate and glue are found to be more effective in controlling the gladiolus thrips than those without. The liberal use of water during dry weather and the use of fertilizer containing powdered naphthalene give favorable indications.

The distribution of the gladiolus thrips, *Taeniothrips gladioli*, M. & S., for 1932 in Michigan was confined largely to the southern half of the state and the infestations were local rather than general.

The loss was most apparent among commercial growers who had acquired new assortments of corms from several sources or where the corms had been stored over winter at high temperatures. A number of experiments were conducted with combinations of the various contact insecticides with and without lead arsenate to determine which would give the most effective control. Unfortunately, the fields were far apart and in each instance it was necessary to rely on the owner to furnish his own spray rig and to apply the spray. While these factors detract from the value of the experiment, certain interesting facts were established. The following four formulae were tested out on a commercial scale. All sprays were applied about four p. m., since at this time more thrips seemed to be feeding in the open than at any time of day.

RESULTS, SPRAYING FOR GLADIOLUS THRIPS 1932

Treatment	No. of sprays	Results
No. 1. Nicotine sulphate 40%–1.6 fluid ounces Soap..... 8 ounces Water.....10 gallons	16 at 48-hour intervals	Foliage good. Saved about 60 per cent of flowers.
No. 2. *Nicotine sulphate 40%–1 pint Liquid lime sulphur—1 gallon Water.....100 gallons	4 at 48-hour intervals	Seemed to kill all thrips hit, but at end of 48 hours thrips were back in great numbers.

*A large commercial field was used and the spray was made up in 50- to 100-gallon batches and allowed to stand several hours before applying. The same formula used immediately on college grounds give better results.

No. 3. Evergreen (normal strength), 1 pint Lead arsenate.... 1 pound Glue..... 5 pounds Water.....50 gallons	8 at 48-hour intervals	Control good. Both flowers and foliage free from thrips.

[1]Journal Article No. 131 (n. s.) from the Mich. Agr. Exp. Sta.

No. 4. Lead arsenate....3½ ounces Derrisol.....4 ounces Glue..... 1 pound Water.....10 gallons	8 at 48-hour intervals	Clean foliage and flowers good enough to exhibit at show.

Of the above sprays those containing lead arsenate and glue gave as high as 95 per cent clean plants, and when these combinations were used in flower gardens where it was possible to irrigate and to fertilize the loss from thrips was negligible.

Nicotine sprays frequently failed in the hands of the grower, because too great a dilution was used or the spray was mixed and allowed to stand for several hours before it was applied. The Derrisol-lead arsenate-glue formula in number four gave the best commercial results during 1932. The liberal use of water and a fertilizer containing naphthalene was also found to be helpful.

A CONTRIBUTION TO THE KNOWLEDGE OF THE WESTERN FLOWER THRIPS, *FRANKLINIELLA CALIFORNICA* (MOULTON)

By Stanley F. Bailey, *University of California*

Abstract

A brief discussion of the distribution, importance, and life history and habits of one of the most cosmopolitan Western thrips.

Only very recently this most cosmopolitan of western thrips, which has been for some time the subject of discussion among systematists, received its appropriate common name from Mr. Dudley Moulton. The Western flower thrips is a member of the sub-order Terebrantia and of the family *Thripidae*. It was first described in 1911 by Moulton as the variety *californicus* of *Frankliniella* (*Euthrips*) *tritici* and Moulton (1929) listed its synonymy and gave it specific ranking. As is the case with many thrips not in the literature among the first ranking economic species, while they are quite commonly observed and casually collected by entomologists, anent their life histories and habits, little is attested. It is the purpose of this paper to record some notes, chiefly of a qualitative nature, concerning *Frankliniella californica* (Moulton) which were gathered during the last three years.

Distribution and Hosts.—The distribution of the western flower thrips according to Moulton (1929 and 1931) is throughout California, Oregon, Washington, British Columbia, Idaho, Montana, Wyoming, Colorado, Utah, Nevada, and also Arizona. Future collections will doubtless expand its record to include Lower California, Mexico, New Mexico, and perhaps Texas.

It would not be the part of discretion to attempt to list fully the hosts of this insect, as it has been collected from practically all wild flowers and fruit blossoms throughout the area of its distribution.

This anthophilous thrips (both adults and larvae) is seldom seen on the exposed surfaces of its hosts and is, according to Shull's artificial classification (1914), an "interstitial species, living in closely concealed situations, as among florets of composite flowers, or in clusters of young leaves." However, on occasion, the adults may be seen in short migratory flights from host to host.

In regard to the distribution of *F. californica* in relation to altitude, it might be said that, in California, the author has collected this species commonly from sea level to about 4000 feet above and it no doubt occurs at much higher levels.

ECONOMIC IMPORTANCE.—Because of the lack of recognition of this thrips as a distinct species among western entomologists, considerable difficulty is realized in attempting to list its economic history separate from *F. tritici* which, in the past, has generally been designated in the western states by the common names of wheat, alfalfa, and flower thrips. The term "flower thrips" in the Western locale, while taxinomically perhaps covering a multitude of errors, is well fixed in the minds of the economic entomologists and growers and serves well to designate an economic pest.

The principal type of damage is the familiar "silver-spotting" on young fruits, particularly peaches, apricots, oranges, and apples. The feeding of both the adults and larvae upon the flower parts and tender unfolding leaf buds of plants, both commercial and ornamental, yearly totals serious losses by resulting in a poor "set" and malformed and stunted fruits. Alfalfa seed producers have often reported considerable loss from this thrips. Hansen (1929) reported "that when green, hard figs are entered by thrips they become inoculated with organisms capable of producing decays and fermentations in the ripening fruit," *F. californica* thus is involved in a new economic role. Of the "flower thrips" Annand (1926) wrote "They are capable of bringing about cross-pollination of some species of flowers under field conditions in spite of their well-known tendency to 'blight' flowers by sucking juices from the ovary and by the destruction of other tender parts of the flower, including the destruction of pollen grains." Although there are no definite figures to present on the losses from this "flower thrips," and, discrediting many reports erroneous and exaggerated, the situation has been well summed up by Essig (1926) who wrote "Although some thrips may

occasion greater losses to one or more crops, this species (the wheat or flower thrips) outdoes all others in the amount of damage in the aggregate to all kinds of crops."

LIFE HISTORY AND HABITS.—*Seasonal History and Ecological Notes.*—In California, the winter is passed chiefly in the adult stage although a few fully grown larvae are occasionally found during the colder months in flower and leaf buds. There is a preponderance of females in the winter and early spring since the males are apparently shorter lived and less resistant to winter conditions. With the advent of spring, the abundance of this thrips increases rapidly and almost any flower cluster shaken into the hand will give up several adults and larvae. Normally, the peak of the infestation on the native hosts occurs in the late spring. Later, with the drying up of the majority of the hosts, the increasing toughness of remaining plants, and the increased temperature, the population drops sharply and, while there is a production of over-lapping generations throughout the summer, no fluctuations are exhibited. However, again in the fall, with the cooler weather and new plant growth the resultant of the first rains, a gradual increase can be noted in abundance.

Some few experiments of a qualitative nature with a climatic cabinet have indicated the following effects: (1) heat rigor set in at about 114°F. (with adults) as compared with 122.5°F. with bean thrips, *Hercothrips fasciatus* (Pergande), (2) adult activity seemed to exhibit an optimum around 80°F. and has a range below that of *H. fasciatus*, and (3) more feeding was done at high humidities (80% and above) by *F. californica* than by *H. fasciatus*. Experiments with low temperatures have shown that (1) mature larvae can survive as long as 5 days at a constant temperature of 32°F., (2) at the end of exposures of 7 days at 32°F. and 5 days at 30°F., about 50 per cent of the adults survived, and (3) the males cannot resist low temperatures as well as the females. Such observations under controlled conditions extend support to the plausible explanation given above of the seasonal variation in abundance.

The adults have quite commonly lived 20 days in the laboratory and a few individuals lived 39 and 44 days. Under field conditions, the adults normally live three or more weeks and, needless to say, during the winter season, they live three or four months. The males, at all times of the year, appear to be much shorter lived than the females.

Dependent chiefly on the temperature, the egg stage extends over a period of from five days (at 80°F. constant temperature) to about fifteen days or more (outdoors) in the early spring. The larval stage con-

sumes from 9 to 12 days under favorable field conditions and, those larvae found during December, January, and February, doubtless require as long as two months to mature. The prepupal stage requires from 1 to 3 days and the pupal stage from 3 days (at 90°F. constant temperature) to 10 days.

Parthenogenesis.—Investigations on this phase of biology almost yearly add new species of thrips to the list of parthenogenetic insects. All unmated females of *F. californica* tested in the laboratory for asexuality gave positive results. The females were isolated previous to emergence from the pupal stage and oviposition was secured on bean leaves. The progeny, which appeared normal in every case, were not reared to sexual maturity.

Copulation.—Mating is very promiscuous and continues intermittently throughout the life of both sexes. An interesting fact was noted in that the Western flower thrips will mate almost immediately after emerging and before feeding oftentimes while the newly emerged bean thrips will not copulate without first having fed.

Migration.—In general, definite migrations in this order, with the possible exception of the pear thrips, are not recognized. The forced shifting of hosts which takes place on the part of *F. californica* and many other thrips in the early summer (in California) is a gradual migration or "infiltration" caused by the drying up of the wild hosts. It is at this time that crops are exposed to infestations. Then again, in the late summer and early fall, as the crops mature and the foliage toughens, thus hampering both feeding and oviposition, the adults in many cases gradually transfer their activities back to native hosts. A forced migration is occasioned by *F. californica* when the cover crops are plowed under and also when alfalfa fields are mowed. At such times adjacent crops and ornamentals often become very badly infested. Normally, during the middle of the day, the adults are not seen upon the exposed portions of the host, but, in the early morning and late afternoon, they very frequently are seen running about among the buds and flowers and even making short flights from flower to flower.

Abundance on Hosts.—Of the long lists of hosts, some plants seem to offer more favorable conditions to *F. californica* than others for, while found in almost every flower, its abundance varies notably. The reasons for this variable condition are probably several, the chief of which is the morphology of the flower itself, the characteristics of which may or may not offer good protection, be of sufficient succulence to allow feeding and oviposition, and have a blooming period of suffi-

cient length to sustain larval development. Large numbers of this thrips are found particularly on alfalfa, *Ceanothus* spp., and *Brassica* spp.

Other Activities.—Such activities as hatching, feeding, pupation, and oviposition occur in a normal manner representative of the order. Nevertheless, it might be well to state that the eggs are deposited in the tenderest portions of plant tissues and, under magnification, may be seen as minute swellings. Upon hatching, the minute, translucent white larva begins feeding with the typical "rooting" motion of the mouth cone. Only one larval molt on the host has been observed. The larvae, together with the adults, feed gregariously. The larva, when mature, drops from the host to the ground and there seeks a suitable place to transform. Pupae may be found from the surface among debris to 3 or 4 inches below in crevices, under clods, etc., depending on the type of soil. The mature larva does not form a cell or spin a cocoon, it remains quietly resting in its chosen place and there molts, passing through a short prepupal stage, and after again molting, obtains the pupal stage. With another and last molt, the adult emerges from the pupa and crawls to the surface and thence on to the host by short hops and flights.

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THE RELATIONSHIP OF APHIDS TO THE TRANSMISSION OF YELLOW DWARF OF ONIONS[1]

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ABSTRACT

Yellow dwarf, an insect-borne virus disease of the cultivated onion, is discussed. Acquisition and dissemination from diseased to healthy onions are inseparably linked with insect vectors. Over 50 different species of aphids have served as carriers in the experimental tests. So far as known the virus passes winter only in dormant bulbs (diseased bulbs in field and storehouse), which serve as source of inoculum at beginning of each season. Control may be accomplished by complete destruction of bulbs left in the field coupled with planting of disease-free sets and mother bulbs grown in non-infested areas, thus breaking the association of vectors and cause of the disease.

Yellow dwarf is an insect-borne virus disease affecting the onion plant. It is of a systemic nature and is closely associated with the growth and development of the onion, which serves as a very propitious host. Some facts relevant to the relationship existing between its causative agent and certain aphids have been discussed in previous papers. Also sufficient experimental evidence has been presented to establish the rôle played by these insects in carrying the inoculum from diseased to healthy onions and to prove that the epiphytotics of the disease are inseparably linked with the fortunes of the vectors. In the furtherance of these studies recent work at Pleasant Valley, Iowa, has added many species to the list of potential carriers and has given valuable data on their occurrence and habits in the onion fields.

The first diagnostic features of yellow dwarf become visible in the young onion sets on the fourth or fifth day after the introduction of the etiologic agent by means of the bites of aphids, and by the twelfth day about 95 per cent of the successfully inoculated plants have exhibited characteristic symptoms. The incidence of the initial appearance of the primary symptoms in 1716 sets, experimentally inoculated through the feeding of aphids, is depicted in the accompanying graph (Fig. 62). When the infective principle is introduced into nearly mature or older leaves, the macroscopic symptoms apparently never appear directly on them. Irrespective of the point of introduction, however, the pathognomonic expressions always show first on the new and rapidly-growing shoots, and all subsequently developing leaves display typical chlorotic areas. Sometimes the disease may be present in a masked or symptom-

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less form for a part or even all of the current growth period. As a consequence of age at the time of infection there is a greater frequency of masking among the older and nearly mature onions.

Plant lice acquire the causal agent during their first feeding upon diseased onions and immediately thereafter are capable of infecting healthy plants, thereby eliminating the hazards that necessarily would

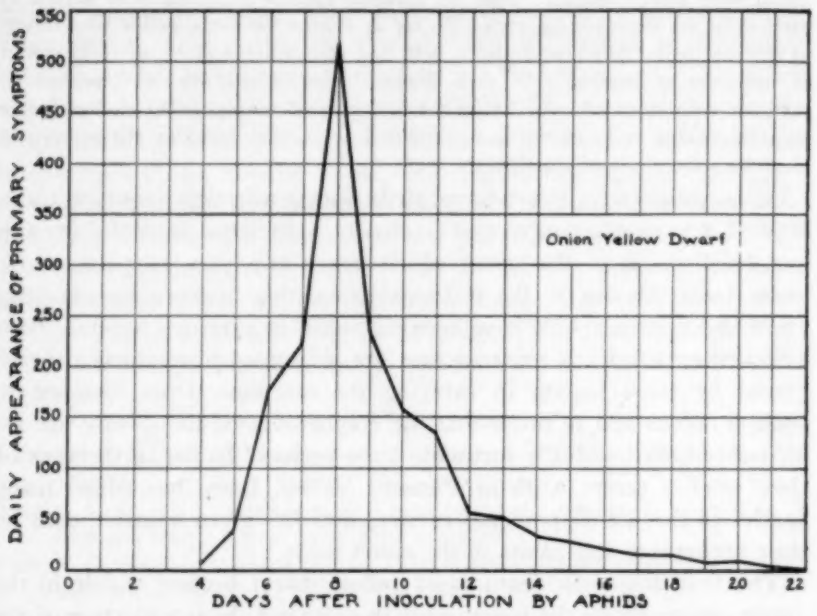

Fig. 62.—Incubation period and daily appearance of primary symptoms of yellow dwarf in 1716 onion sets inoculated by means of the bites of viruliferous aphids.

be encountered should a prolonged incubation period in the insect be obligatory. If there is a latent period in the insect, it is extremely short, and aphids thus seem to have very little, if any, more than accidental connection with yellow dwarf, yet they served as the only important and perhaps sole means of transference of the infective principle under natural conditions. On the third or fourth day after being inoculated by viruliferous plant lice, the growing onion itself becomes a source of infection and harbors the virus throughout life, even though the usual expressions of the disease may be concealed.

Although probably not the autochthonous host, the cultivated onion is a very favorable ambient for the yellow dwarf virus. When transferred from disaesed to healthy plants during the natural process of

feeding of aphids the virus increases in quantity, becomes systemic in its distribution, and usually manifests its presence by the production of definite and characteristic macroscopic symptoms. Moreover, it is capable of living through long periods in the dormant bulb. In the insect, on the other hand, the virus displays not so marked a host-specificity. Here it seems to be incapable of reproducing itself, and in fact soon loses its infectiousness. It has no apparent effect on the insect, and a virus-bearing aphid is not recognizable as such except by a study of the effect of its feeding on the onion. An infected onion thus may serve as an unlimited source of inoculum for the vectors, whereas an aphid, unless having almost constant access to the contagium, can inoculate only a few plants. Therefore, since the disease is not seed-borne and wild hosts are unknown, it is patent that the initial source of inoculum for aphids in the spring is the foliage of bulbs which were infected during the previous season. Under actual field conditions these overwintering "harborers" of the disease include many volunteer bulbs left in the field and waste piles in addition to those infected plants that might have been gathered for transplanting purposes. With aphids as carriers and with diseased bulbs it is possible to infect serially an endless number of plants. *A priori* there is a progressively increasing number of foci of infection for the vectors as the season advances.

Although inoculable, the virus of onion yellow dwarf is not of a highly infectious nature and can not be spread by ordinary contact. Man, insects, and other animals do not serve as passive conveyors of the disease by its adherence to the appendages or clothing, nor can the disease be disseminated mechanically on insect cages and farm equipment. Numerous tests have failed to show that the disease may be transmited by feeding activities of such insects as grasshoppers, beetles, cutworms or other caterpillars, and coleopterous larvae. Tests also have failed to incriminate onion maggots, thrips, bulb mites, and many other primary and secondary pests which ravage the onion plant.

In a recent publication the term "transitory" host was applied to the onion because aphids can not breed, or even live for any appreciable period, when caged upon this plant. The onion seems to serve largely as a place to rest and as a temporary source of nourishment during their fortuitous wandering and migrations. Migratory and summer forms of some species imbibe the juice of the onion very readily whereas others are more or less hesitant about feeding on it. Two species (*Cinara pini* Linn. and *Eulachnus rileyi* Williams) and the stem mothers of certain other species perished in the experimental cages without even at-

tempting to feed upon the onion. Yet some individuals of those aphids living on weeds and cultivated vegetation now and then wander upon the foliage of the onion plant and partake of its sap. Apterous viviparae of some of the more active species, like the pea aphid (*Macrosiphum pisi* Kalt.), were frequently found on onions as far as 100 feet from any other plants. Most aphids, particularly polyxenoid species, feed rather readily on the onion in the absence of customary hosts.

Previous to the establishment of the association existing between aphids and yellow dwarf, very little attention was given to the occurrence of these insects in onion fields. The number of different species as well as the number of individuals of any one species involved in the transmission of the disease depends greatly upon the numbers and kinds of hosts growing in or near onion fields, the numbers of predators and parasites, the weather, and other factors that affect the complexity of the local environment.

During the past summer, May 10, 1932, *M. pisi* (Kalt.) was the first plant louse found at Pleasant Valley feeding on onions; three days later plat counts showed the population of this species to average around 2500 individuals per acre in fields bordering alfalfa. In fact the pea aphid was the only species of any consequence in the onion fields up to the middle of May. By May 20 the bean aphid was as common and generally distributed in the onion fields as the pea aphid. Thereafter, the bean aphid (*Aphis rumicis* L.), the sunflower aphid (*Aphis helianthi* Monell), and the lamb's quarters aphid (*Hyalopterus atriplicis* L.), together with several other species, were also present.

The melon aphid (*Aphis gossypii* Glover) was the commonest species in many onion fields during the latter part of July, both in 1931 and 1932. Records for several seasons show the apple grain aphid (*Rhopalosiphum prunifoliae* Fitch) to have been by far the dominant species after the onion crop was harvested and that it was largely responsible for the spread of the disease among volunteer onions in the fall.

In many onion fields certain species of weeds, such as lamb's quarters, clover, purslane, grasses, and the like, succeeded in establishing themselves, especially during periods of wet weather. Irrespective of size or location of weeds in the field, they soon became populated with plant lice. Not infrequently from 50 to 75 pea aphids were found on sprigs of clover here and there in large onion fields. As many as 300 specimens of the bean aphid have been collected on a single weed; and numerous other species of aphids have also been found in numbers on weeds in onion fields. Eventually, at least in many cases, the weeds

are cut or pulled by the growers, thus forcing both nymphs and adults to migrate in search of food. Under such conditions it is not uncommon to find from a few to 30 or more aphids feeding on a single onion plant near a recently cut weed. As an illustration of the inherent tendency of many species to wander, individual pea aphids have been observed to feed upon four different onion plants within a period of 30 minutes. This restlessness no doubt is due somewhat to the fact that the onion is not a satisfactory host.

In the course of the experiments in the vicinity of Pleasant Valley and at Ames, Iowa, many different species of aphids have been taken on the foliage of onion, weeds in onion fields, and cultivated and wild plants in bordering and nearby areas. As a consequence of their bites the virus of onion yellow dwarf has been transferred from diseased to healthy onions under field and greenhouse conditions by the following species of the family Aphididae: *Amphorophora rossi* Hottes and Frison, *A. rubi* (Kaltenbach), *Anoecia* sp., *Aphis ageratoidis* Oestlund, *A. cardui* Linnaeus, *A. decepta* Hottes and Frison, *A. forbesi* Weed, *A. gossypii* Glover, *A. helianthi* Monell, *A. laburni* Kaltenbach, *A. oenotherae* Oestlund, *A. oestlundi* (Gillette), *A. pomi* DeGeer, *A. rumicis* Linnaeus, *A. viburnicola* Gillette, *Brevicoryne brassicae* (Linnaeus), *Calaphis betulella* Walsh, *Capitophorus flaveolus* (Walker), *C. ribis* (Linnaeus), *Chaitophorus quercicola* (Monell), *C. viminalis* Monell, *Clavigerus salicis* (Linnaeus), *Drepanaphis acerifoliae* (Thomas), *Hyalopterus atriplicis* (Linnaeus), *H. pruni* (Geoffrey), *Hysteroneura setariae* (Thomas), *Macrosiphum ambrosiae* (Thomas), *M. gei* (Koch), *M. gravicornis* Patch, *M. impatienticolens* Patch, *M. pisi* (Kaltenbach), *M. purpurascens* (Oestlund), *M. rosae* (Linnaeus), *M. rudbeckiae* (Fitch), *M. taraxaci* (Kaltenbach), *Microsiphum artemesiae* (Gillette), *Monellia caryella* (Fitch), *M. caryae* (Monell), *Myzocallis alhambra* Davidson, *M. asclepiadis* (Monell), *M. ononidis* (Kaltenbach), *Myzus cerasi* (Fabricius), *M. monardae* (Williams), *M. persicae* (Sulzer), *M. porosus* Sanderson, *Periphyllus negundinis* (Thomas), *P. populicola* (Thomas), *Prociphilus corrugatans* (Sirrine), *P. fraxinifolii* (Riley), *Rhopalosiphum prunifoliae* (Fitch), *R. pseudobrassicae* (Davis), *R. rhois* Monell, *Thripsaphis ballii* (Gillette), and several other species not as yet determined. The writers are greatly indebted to Dr. F. C. Hottes for the identification of the aphids.

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OBSERVATIONS ON THE FEEDING HABITS OF THE POTATO PSYLLID (*PARATRIOZA COCKERELLI* SULC.) AND THE PATHOLOGICAL HISTORY OF THE "PSYLLID YELLOWS" WHICH IT PRODUCES

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ABSTRACT

Studies of histological sections of *Paratrioza cockerelli* in feeding position on potato foliage show the setal sheath penetrating the mesophyll into the border parenchyma immediately surrounding the vascular bundles. The majority of feeding seems to occur in this region. Further examinations of diseased leaves and stems reveal abnormally large deposits of chromoplastids, probably starch granules, in the chlorenchyma of the leaf and in the cortex and pith of the stem.

Investigations, carried on during the past three years at the New Mexico Agricultural Experiment Station to determine the more important insect pests and plant diseases limiting the production of Irish potatoes in the state, have revealed that the Potato Psyllid (*Paratrioza cockerelli* Sulc.) and the "Psyllid Yellows" disease which it produces, is one of the most important factors concerned.

Altho the injurious effect of the feeding of this insect has been recognized since about 1915, "Psyllid Yellows" as a distinct disease was first described by Richards (1) in 1927. It is widely spread throughout the Rocky Mountain potato growing regions and is regarded as one of the most serious potato diseases and difficult to combat. The exact nature of the causal factor has not been demonstrated and the insect vector is not easily controlled by insecti-

cides ordinarily employed for sucking insects. The observations and experiments described in the following discussion were conducted to determine whether any relation could be found to exist between the external symptoms of the disease and the plant tissues invaded and altered by the feeding of the Potato Psyllid.

SYMPTOMS.—Psyllid Yellows is sometimes confused with potato leafroll because of the rolling, "cupping" and yellowing of the leaves, and with Rhizoctonia because of the production of aerial tubers. The following distinctive characters, however, have been outlined by Richards (2).

1. The early symptoms consist of an upward rolling of the basal portions of the young leaflets at the tips of the branches, this condition becoming more pronounced as the disease progresses. In most varieties of potatoes a distinct yellowing of the foliage accompanies this symptom or in Bliss Triumph and Cobbler varieties a reddish or purplish discoloration appears in the rolled portions.

2. The nodes, particularly those of the younger portions of the stem, become enlarged causing the stems to stand out from the main stalk at a characteristic angle (Plate 37, Fig. 1).

3. All buds become abnormally active resulting in the production of accessory shoots and aerial tubers. The entire plant assumes a "stalky," "bushy," or "rosetted" appearance. (Plate 37, Figs. 1 and 2).

4. Below ground the proliferation takes the form of numerous small tubers, in "chains" along the older stolons or in clusters at the nodes. The tubers thus formed frequently give rise to sprouts which develop into leafy branches when near the surface or into secondary tubers which further produce new plants.

5. In the later stages of the disease the older leaves become yellow, develop necrotic brown areas, and drop, leaving only the younger adventitious foliage on the primary stems. (Plate 37, Fig. 2).

Observations in New Mexico on Cobbler and Red McClure varieties confirm these symptoms as characteristic.

INOCULATION EXPERIMENTS.—A series of experiments in which Paratrioza nymphs were transferred from diseased to healthy potato plants were carried out and it was observed that the disease could be readily produced in healthy plants in field cages by this method of infection. The producing of the disease in the greenhouse or in laboratory cages was less certain, however, light intensity apparently being an important factor concerned with the producing of characteristic symptoms. Nymphs reared from eggs deposited by adults

on healthy potato plants failed to produce the disease, supporting the conclusions of Binkley (3) that the infective principle is not carried to the next generation through the egg or that the simple mechanics of feeding does not produce the disease.

HISTOLOGY OF THE FEEDING PUNCTURES.—To further determine whether the mechanical nature of the feeding as revealed by study of the histological features might produce systematic disturbances sufficiently severe to cause the symptoms already described, serial sections were made of nymphs feeding on potato foliage. Technique similar to that employed by Horsfall (4) in investigating the feeding punctures of aphids and by Smith and Poos (5) with leafhoppers was used.

The following observations and comparisons developed as a result of these studies. The Potato Psyllid is primarily a leaf feeder, the majority of feeding in the field being carried on from the lower surface of the leaf. However, a few individuals have been observed feeding on the stems or petioles and some feed from the upper surface as noted by Knowlton and Janes (6). This feeding position may be due to shade rather than preference for any particular part of the plant.

The beak consists of a pair each of greatly attenuate mandibles and maxillae (Plate 38), Fig. 1), and is readily traceable in serial sections. The setal sheath, as described by Horsfall for aphids and by Smith and Poos for leafhoppers of the genus Empoasca, is not as distinct or constant in occurrence as for these other insects. Penetration is not necessarily intracellular nor do the mouth parts always follow the middle lamella. Actual penetration of cells by laceration frequently occurs (Plate 38, Fig. 2), particularly in the region of the spongy mesophyll, or the beak traverses the intercellular spaces until it reaches the border parenchyma surrounding the vascular bundle. A short setal sheath frequently does occur, however, after the beak has reached the border parenchyma and the particular cells injured, (Plate 38, Fig. 3) can be determined. The phloem parenchyma cells which border the xylem in the larger veinlets or the companion cells and modified parenchyma which form the major portion of the vascular bundles in the smaller veinlets are the regions of the leaf where most extensive feeding occurs.

Penetration of the xylem itself occurs only occasionally and no extensive plugging of the xylem of the leaves or stems, as recorded by Smith and Poos for *Empoasca fabae*, was observed. Frequent alter-

ations in the phloem, particularly the border parenchyma, were observed, however, in the form of destruction and collapsing of these cells and the filling of the resulting cavities with granular materials. (Plate 38, Figs. 4 and 5). Parenchyma cells adjoining the injured portions often contained starch granules in noticeable numbers (Plate 39, Fig. 1). Alterations in the size and position of the nuclei and chloroplasts were occasionally observed in connection with such changes.

HISTOLOGY OF THE DISEASED STEMS.—The effect of these feeding operations in the leafy portions of the plant are also noticeable in the stems. Sections of diseased stems and petioles show abnormally large deposits of starch granules in the cortex and pith (Plate 39, Figs. 2 and 3), and this condition increases with the severity of the disease. Granular deposits, disintegration of the phloem or other bundle alteration as described by Artschwager (7, 8) for potato leaf roll and other "phloem necrosis" diseases, were not observed. In connection with the thickening and enlarging of the stems an attendant thickening of the cell walls was noticeable however.

CONCLUSIONS.—This study, although still incomplete allows the following conclusions and generalizations:

1. The nature of the feeding of the Potato Psyllid is not such as would induce Psyllid yellows symptoms by wholesale destruction or mechanical plugging of the vascular tissues.

2. The principal objective, being as it is in the border parenchyma surrounding the vascular system, apparently interferes with translocation at inception. Since a chlorotic condition is one of the symptoms of Psyllid Yellows this inhibition of translocation is very probably complicated by disturbances in the photosynthetic activities of the plant.

3. This region of extensive feeding is so located that primary disturbances could readily be accentuated by the injection of some infectious principle or disturbing enzyme.

Further investigations are in progress, to determine more exactly by microchemical methods, the physio-chemical nature of the effect of the feeding activities herein described.

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EXPLANATION OF PLATES

PLATE 37

1—Irish Cobbler Potato affected with Psyllid Yellows (left) compared with healthy plant of same variety, (right); 2—Irish Cobbler Potato Plants affected with Psyllid Yellows. Plant on right shows aerial tubers and "rosette" type of adventitious foliage. Plant on left shows enlarging of stems and loss of all primary foliage.

PLATE 38

1—Sagittal section thru anterior part of *Paratrioza cockerelli* in feeding position on potato leaf blade showing structure of "beak" and penetration of epidermis. (× 49). 2—Cross section of potato leaf blade showing setae of *P. cockerelli* penetrating lower epidermis and spongy mesophyll. (× 120). 3—Same showing setae crossing mesophyll and penetrating a small vascular bundle. Setal sheath well developed in distal portion of feeding region. (× 230). 4—Cross section of spongy chlorenchyma region of leaf blade illustrating feeding injury. Two parenchyma cells have collapsed and resulting cavity is filled with granular material. Parenchyma cell at lower right shows an enlarged nucleus. (× 418). 5—Enlarged view of same showing distal portions of setae embedded in collapsed parenchyma cell.

PLATE 39

1—Parenchyma cell adjoining injured region illustrated in Plate 38, Fig. 5, filled with starch granules. 2—Cross section of potato stem (internodal region) affected with Psyllid Yellows showing deposits of starch granules in cortex, endodermis and pith. (× 96). 3—Longitudinal section of same. (× 96).

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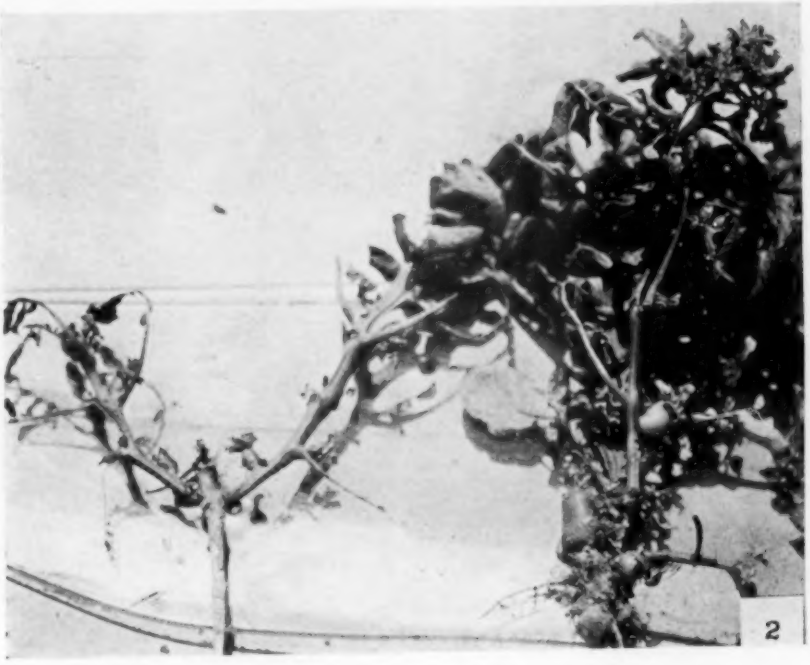

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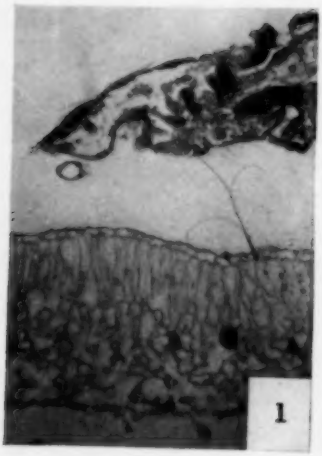
Plate 38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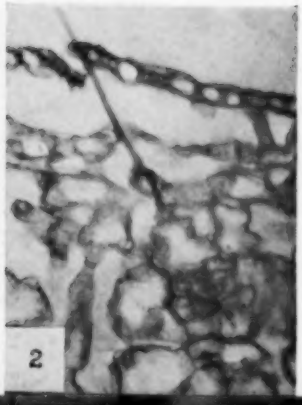
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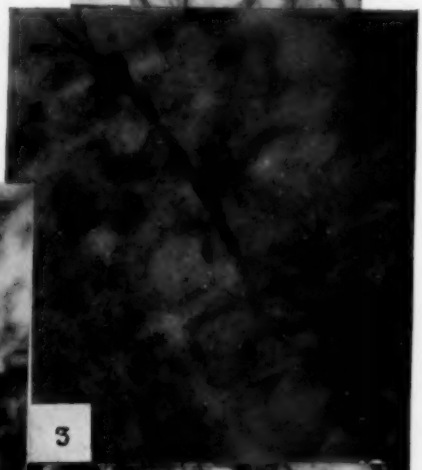
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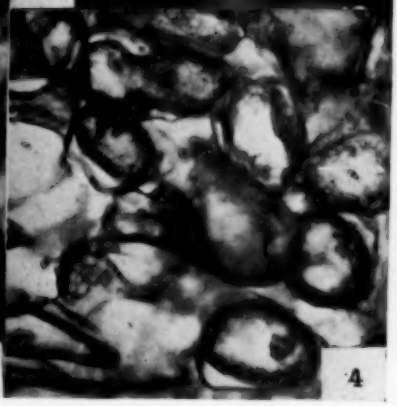
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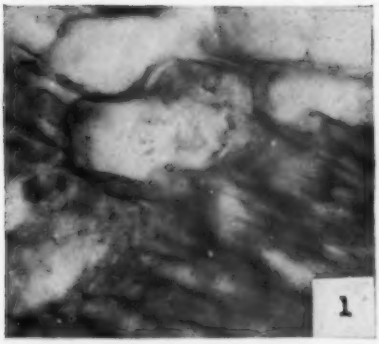

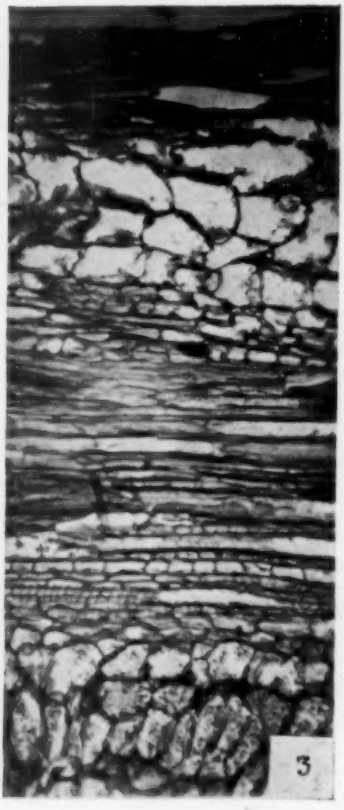

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VARIATION IN THE POPULATION DENSITY OF THE CALIFORNIA RED SCALE, *AONIDIELLA AURANTII* MASK., IN A HILLY LEMON GROVE

By WALTER EBELING, *University of California Citrus Experiment Station, Riverside, California*

ABSTRACT

Observations made in a hilly lemon grove indicate that the more elevated portions of the grove have the highest average temperature and that the population density of the California red scale in this grove is a function of temperature.

A number of years of rather extensive field experimentation with the California red scale, *Aonidiella aurantii* Mask., in certain hilly sections of southern California, such as the Yorba Linda district, had led the writer to believe that citrus trees in the more elevated districts are usually more heavily infested with red scale than those in the lower districts; and, likewise, in any given grove, the trees in the highest portions of the grove usually have the greatest infestation of scales. It is a common observation that the red scale can be more easily controlled by the usual control measures in the less elevated portions of groves than on the higher elevations. This would indicate that more severe or more frequent control measures could be advantageously employed in the higher areas of the grove.

It has been our observation for a number of years, and has been indicated by Knight (1931), that the mortality of insects from oil sprays is lower on heavily infested fruits than on lightly infested fruits. It is possible that the lower mortality of insects on heavily infested fruits may be due to the roughened surface of the fruit, caused by the encrustation of scales, causing a lighter deposit of oil. The effect of the character of the surface sprayed on the oil-depositing qualities of the spray is discussed by Smith (1932). It would also appear that when trees are so heavily infested with red scale that the insects actually overlap at their margins, the mortality resulting from fumigation would be somewhat lower than when the trees are more lightly infested, due to the protection afforded by the overlapping scale margins.

With these practical considerations in mind, it was deemed advisable to secure more exact data on the influence of elevation upon the population density of the red scale. A lemon grove typical of the more hilly portions of the Yorba Linda section in California was selected for this purpose (Figure 63). Beginning at the northeast

corner of the grove, the number of insects per given unit was counted on every fourth tree throughout the grove. The unit comprised a portion of a branch one inch in diameter and two inches in length. Only the insects seen from one aspect were counted. Twenty units, selected at random throughout the tree, were examined.

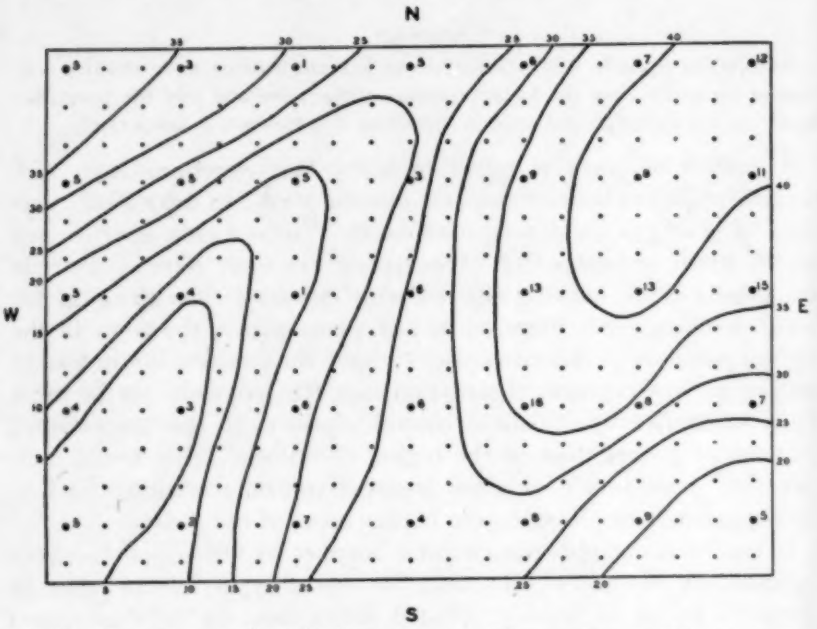

Fig. 63.—Contour map of a hilly lemon grove. The numbers outside the border of the chart indicate relative elevation in feet. The numbers inside the border are a comparative index of the number of red scale occurring on every fourth tree throughout the grove.

The numbers in Figure 63 are the number of insects counted, divided by 100; thus 1200 insects were counted on the tree situated on the northeast corner of the grove; 1100 insects were counted on the fourth tree south of the first, etc.

A contour map of the grove was made to show the variation in elevation throughout the grove. Beginning at the lowest elevation of the grove, arbitrarily designated as 0.0 feet, the higher elevations were successively determined by sighting along a level to the top of a five-foot pole situated at a lower and previously determined elevation. The various elevations throughout the grove are indicated by the contour lines in Figure 63.

Two thermographs were placed in the grove: one at the 40 ft. level and one at the 0.0 ft. level. Figure 64 shows the average temperatures at these elevations from April 17 to May 15, 1932. The average temperature at the 40 ft. level was 4.73°F. higher than that at the 0.0 ft. level.

The greatest variation in temperature occurred at night. During the day the temperatures at the two elevations became more alike, and

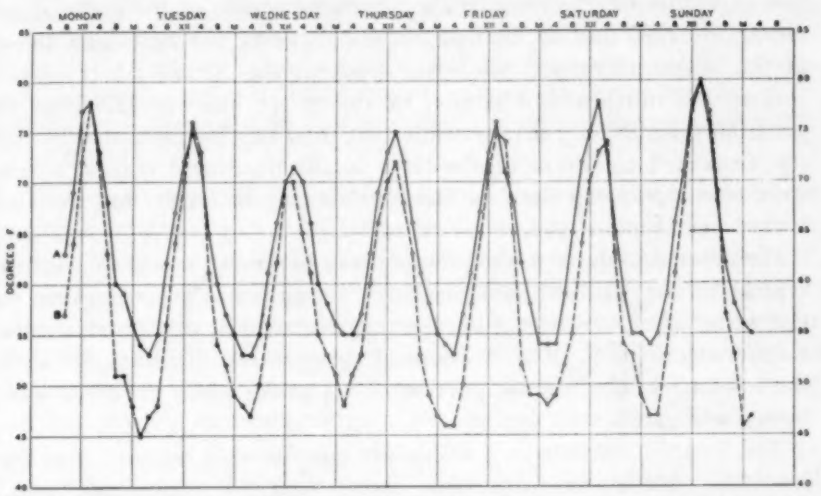

Fig. 64.—Chart showing the average temperature over a one-month period at the highest portion (A), and the lowest portion (B), of a hilly lemon grove.

in the early afternoon the temperature at the lower elevation was in a few cases higher than at the higher elevation. This may be due to the influence of the cool afternoon breeze blowing from the ocean, which affects the higher elevation before the lower, for the lower elevation is bounded on all sides by more elevated land protecting it from the direct influence of the ocean breezes.

Since the grove has received uniform cultural treatment and pest control measures, the density of the red scale population may be assumed to be a function of temperature. Variation in elevation alone, however, may not be the sole factor affecting the temperature of the insects' immediate environment. Thus the hilltops have a shallow and impoverished soil as compared with the lower lands; consequently the trees on the hilltops are smaller and more open than those in the lowlands, and admit more sunlight and afford a warmer environment for the insects occurring on them. The 4.73°F. difference in

temperature between the lowest and the highest elevation in the grove may not in itself be sufficient to cause the differences in population density which were found in the grove.

On the other hand, an impoverished soil may produce trees in such a weakened condition that they are no longer a suitable host for the scales, and in this case a lower population may be found on the small, open trees than on the thrifty trees. As can be seen by an examination of Figure 63, the trees on the northwest corner of the grove at an elevation of 30 and 35 ft, had no more insects per unit than those at the lowest elevation; while the trees at the 30 and 35 ft. elevation in the northeastern section of the grove had several times as great an infestation. It is possible that this may be accounted for by the weakened condition of the trees in the northwest corner, which were on a very steep slope, as the contour map indicates, and were on a very poor type of soil.

The grove considered in the present paper presents a topography rather typical of the Yorba Linda district. Temperature records given to the writer by the owner of another citrus grove in this district show a difference of 6°F. to 10°F., depending upon the humidity, between the lowest and the highest portion of his grove when the trees were being fumigated.

The foothill districts as a whole are considerably warmer than the lowlands, which constitute the major part of the citrus area. For this reason they are largely planted to lemons, which are less frost resistant than oranges. These foothill districts have been called "resistant red scale areas" because of the difficulty encountered in controlling the red scale by the ordinary control measures. While the greater resistance of the strains or races of red scale found in some areas has been demonstrated by Quayle (1922), it is not known to what extent "resistance" as applied to red scale in the foothill districts is due to the higher temperature prevailing in these districts. It is not known, also, to what extent the apparent resistance in these districts may be accounted for by the fact that the lemon is the preferred host of the red scale.

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NATURAL CONTROL OF THE CITRUS MEALYBUG[1]

By F. R. COLE, *Bureau of Entomology, United States Department of Agriculture*

ABSTRACT

The introduction into California of certain natural enemies of the citrus mealybug (*Pseudococcus citri* Risso) has apparently accomplished its control and brought the population to a very low point. The coccinellid beetle, *Cryptolaemus montrouzieri* Muls., and the hymenopterous parasite, *Leptomastidea abnormis* Gir., can be credited with the major part of this reduction of the citrus mealybug. The present paper gives a brief history of the pest in California and some observations on the predators and parasites present during the early outbreaks and continuing up through the year 1918. There is a rather complex interrrelation of the various parasitic enemies, the most important of which are pictured on the accompanying chart.

The citrus mealybug (*Pseudococcus citri* Risso) is now at a very low point in its population, perhaps at its nadir, and it is possible that its role as an important citrus pest is now at an end. On the other hand, it may be a part of a great moving cycle, destined to ascend from its valley to new peaks of importance. Various insects have at times held the spotlight in the history of pest control in California, such as the San Jose scale, the cottony-cushion scale, the black scale (still important), the two mealybugs of citrus, and now the California red scale.

Our earliest references to the citrus mealybug in southern California are concerned with *Pseudococcus citri*, but there was some confusion with *P. maritimus* Ehrhorn, a less abundant species. The citrus mealybug has long been recognized as a greenhouse pest in many parts of the United States, the known records dating back to 1885. In California it was attracting some attention about 1900, becoming a real menace from 1904 to 1910, and constituting a major pest of citrus up to 1930 (*3, 8*). The problem was complicated by the appearance in 1913 of another mealybug, *Pseudococcus gahani* Green, known as the citrophilus mealybug, soon to take front-page notice from the older established *P. citri*. In 1920 *P. citri* was still the most important. Smith and Armitage (*14*) have traced the history of the mealybug in a recent bulletin.

[1]The summarized records given herewith are based in large part on the unpublished laboratory and field notes accumulated by R. S. Woglum while an employee of the United States Bureau of Entomology. The writer was an assistant at Mr. Woglum's laboratory in 1914 and 1915 and is greatly indebted to him for the privilege of examining and making use of these old notes.

Quoting from an old report on *P. citri*, in a bulletin of the Claremont Pomological Club (*15*):

> From close observations in a badly infected district I would say that the mealy bug is by far the most damaging and dangerous pest now in the Southland. I believe that the citrus industry is threatened by the invasion of this insect as it has not been threatetned since the ravages of the *Icerya purchasi*, before it was checked by its natural enemy, the *Novius* (*Vedalia*) *cardinalis*. In prolificness, in endurance to hardships, in power to spread and to do damage no pest in the South is nearly its equal.

This was the opinion of a county agricultural commissioner in which most growers and field men of the period concurred.

In the writer's opinion, which is based in part on observations in 1914 and 1915, credit for control of the citrus mealybug should be given to introduced natural enemies, the most important probably being, as Smith and Armitage (*14*) point out, the beetle, *Cryptolaemus montrouzieri* Mulsant, and the hymenopterous parasite, *Leptomastidea abnormis* Girault. The native predators and parasites have also had a part in this work, but they have been found to be more or less inefficient, principally because of parasites preying upon them. Other, less obvious, biotic factors, as well as climatic changes, may have had some influence on this control.

Cryptolaemus montrouzieri Muls. (named for Abbé Montrouzier by Mulsant) was collected by Koebele in Australia and brought to California in 1892. Mr. Koebele found the beetle preying on mealybugs in Fiji, Ceylon, and southern China. When introduced into California, it found conditions in the coastal area to its liking and was soon a factor in mealybug control in San Diego (*5, 8, 11, 23*); in most cases, however, it required artificial breeding under controlled conditions in order to attain any great numbers. There is some difference of opinion as to the value of these beetles, commonly called "cryps" in the industry, but when reared in insectaries by the modern methods devised by Smith and Armitage, they are unquestionably an important control factor. This beetle has failed to establish itself in Egypt and Palestine, owing largely to climatic factors, as pointed out by Doctor Bodenheimer (*1, 2*). In Palestine it has six generations against eight for the mealybug, and in addition can not survive the cold of winters or the moist heat of the summers. It has a developmental zero of 10.3°C. against 8.4°C. for the mealybug. The beetle lays from 200 to 750 eggs over a period of three to five months; the mealybug averages about 200 eggs. At Pasadena the egg stage of *C. montrouzieri* is

about 5 days, the larval stage 14 days, the pupal stage 11 days. The greatest feeding by the beetle is done in the larval stage, this stage in the 1917 records accounting for from 319 to 407 of the first and second stage mealybugs and from 60 to 71 of the third and fourth stage host. Adult feeding is more limited and has been recorded by various writers.

Leptomastidea abnormis Gir.—There have been some errors in the recording of the first introduction of this species into California. The first specimens of this important little parasite were collected by Prof. H. J. Quayle in Sicily in 1912, some of the original material now being in the United States National Museum collection. Two years later H. L. Viereck, while an agent of the California State Department of Agriculture in Sicily (*19*), collected numerous mealybug masses at Palermo and shipped them out to the State insectary; from this material Harry S. Smith bred out the first of these little encyrtid parasites, then known as *Leptomastix* sp. (*12*). There has been considerable juggling of the species first placed in the genus *Leptomastix*, a genus originally described without designation of species by Foerster in 1856, and about twenty years later established on the genotype *histrio* by Mayr. Howard described *dactylopii* in 1885 from specimens bred from *Pseudococcus citri* in Washington, D. C., and in Grenada, West Indies. In 1887 Ashmead described a third species, *L. tinaevora* from Florida—not a mealybug parasite, however. In 1915 Girault (*9*) made a study of the little Sicilian mealybug parasite and placed it in his genus Paraleptomastix under the species name *abnormis*, In 1918 Timberlake (*17, 18*) erected a new genus, Tanaomastix, with *abnormis* as the type, and included with it the old species *albiclavata* (*Aphycus albiclavatus* Ashmead, 1905, Philippines), together with a California parasite of the cypress mealybug (*Pseudococcus ryani* Coquillett), named *T. claripennis* Timberlake. The little banded-winged *abnormis* now seems to have found a resting place in Mercet's genus Leptomastidea.

Whatever its systematic position, *L. abnormis* has been remarkably effective on *Pseudococcus citri* in California, on which it is almost specific. It does not seem able to breed through on *Pseudococcus gahani* or *P. maritimus* (*4*) and is only occasionally bred from *P. krauhniae* Kuwana. Bodenheimer considers the species too sensitive to climatic factors to be of value in Palestine. In California its developmental period from the start of the egg stage to maturity may range in length from 21 to 49 days, and the adults have been kept alive for 34 days. Un-

fertilized females produce males only, and only one parasite develops from a host, although three eggs may be laid and Armitage and Smith (*13*) have recorded as many as 100 under forced conditions. The mealybug continues to move about until the pupation period of the parasite, at which time the host dies and forms a globular shell, or tunica, about the parasite pupa.

INTRODUCED PREDATORS OTHER THAN CRYPTOLAEMUS.—(*Rhizobius*) *Lindorus lophanthae* Blaisdell, also known in literature as *Scymnus marginicollis* Mann. (*7*) was introduced into California by Koebele, but it was found to have existed in the State long before this. It is of very little value in feeding on mealybugs, being more of a scale parasite, particularly abundant in some areas infested with the red scale.

Scymnus bipunctatus Kugelann was first believed to be (*Cryptogonus*) *Aspidimerus orbiculus* (Gyll.), and was secured by George Compere from the vicinity of Manila in the Philippine Islands. In 1911 and 1912 many colonies of this species were collected and sent out by the State Horticultural Commission, with great hopes for it as a means of controlling the mealybug. Essig published the first complete account of it in 1911 (*6*) from material first put in cages in July, 1910. Insectary tests were promising, but the beetle failed to establish itself under orchard conditions.

Rhizobius ventralis Erichson was introduced from Australia by Koebele in the early nineties as a parasite of the black scale. It was said to be one of the most numerous coccinellids in South Australia and Victoria, occurring in remarkable numbers around a soft scale on eucalyptus. The beetles at Melbourne, Australia, were commonly parasitized by a species of Homalotylus, but these parasites were in turn checked quite efficiently by a secondary. Koebele reported twelve other promising species of Rhizobius from the Australian region, but none has been of importance in mealybug control; one, *Lindorus lophanthae*, is mentioned above.

INTRODUCED INTERNAL PARASITES OTHER THAN LEPTOMASTIDEA.—There have been several attempts to introduce internal parasites of the mealybugs but, except for the Leptomastidea, most of them have been without success, particularly in the case of *Pseudococcus citri*. About 1908 George Compere brought in three then unknown parasites, one of which was recovered by Essig in Ventura County and determined as *Chrysoplatycerus splendens* Howard (*7, 8, 16*). This parasite breeds slowly and is of little economic importance.

NATIVE PREDATORS.—*Hyperaspis lateralis* Mulsant (*7*) is a native

coccinellid found feeding on mealybugs in several parts of the Southwest. The dark beetles are 2 to 3 mm. long, the elytra shining black with three red or pale spots. The white woolly larvae look like those of the Cryptolaemus. The species is occasionally of local importance, the larvae and adults being feeders on various mealybugs, but a parasite of the genus Homalotylus is so abundant as to ruin its efficiency. The length of the egg stage is from 8 to 15 days, that of the larval stage from 15 to 20 days, and that of the pupal stage from 14 to 22 days. The female lays from 50 to 558 eggs. The larvae consume on an average about ten small mealybugs and four of the third and fourth stage per day. The adults eat comparatively few mealybugs.

Scymnus sordidus Horn (*7*) is a small brown ladybird beetle common to most of southern California. It is a fairly effective worker on the mealybug but not a real factor in control.

Scymnus guttulatus Leconte, a black species with reddish markings, was at one time bred in considerable numbers in the state insectary at Sacramento. In 1909 Essig made some trials of about 1,000 beetles in Ventura County with little success, those liberated out-of-doors being lost completely. Essig quotes Casey's description of the beetle, published in 1899 (*6*).

Scymnus nebulosus Leconte has done some effectual work in feeding on the citrus mealybug. The adults are very small beetles, brown, with darker markings. The larvae feed on aphids and scale insects other than mealybugs.

The brown lacewings are important in mealybug control, and are sometimes given credit for being the best of all mealybug enemies, but they are not easily raised in confinement and too many parasites attack them. The three species of *Sympherobius* studied at Pasadena from 1914 to 1918 were *californicus* Banks, *barberi* Banks, and *angustus* Banks. They can be distinguished in all stages and have good larval characters. The sexes appear to be about equal in numbers and the adults live about 10 to 15 weeks. Very few adult mealybugs are eaten by these lacewings, but the first and second stages are consumed rapidly. The adult lacewing eats the whole mealybug, averaging about four per day. It also consumes considerable honeydew.

The egg stage of *S. barberi* lasts about 7 days, the larval stage about 10 to 18 days, and the pupal stage about 11 days. The life history of the other two species, *californicus* and *angustus*, is essentially the same.

The lacewing larvae eat comparatively few mealybugs, but they do

consume many mealybug eggs. For example, 13 larvae of *S. barberi* ate on an average 373 eggs, and during the same period ate on an average 6 of the first and second stage larvae and 0.6 of the third and fourth stage mealybug.

One lot of *S. californicus*, with the larval period extending 13 to 16 days, ate an average of 1,043 mealybug eggs; another lot, with larval periods lasting from 14 to 22 days, ate an average of 864 mealybug eggs. These larvae each ate an average of about 270 small, first-stage mealybugs.

S. angustus is usually less common about mealybug infestations and, from the few records taken, is less efficient as a feeder. An idea of the egg laying of this species may be gained from the following: 379 eggs in 44 days, 86 eggs in 50 days, 610 eggs in 34 days, and 496 eggs in 47 days. From 95 to 100 per cent of these eggs hatched, the egg stage averaging 11 days in summer but lengthening to 33 and 34 days during December and January.

In all the species of Sympherobius there is considerable larval mortality during the early stages, most apparent in the first stage, particularly at temperatures around 95°F. and over. In hot weather the adults and larvae collect on the cool north side of the trees, occasionally getting on the ground on leaves under the trees. The newly hatched larvae may destroy a few of the unhatched eggs near them, usually a very small percentage. A few lots of *S. barberi* had unusual tendencies to cannibalism, sometimes eating as many as 50 per cent of the total hatch.

Bodenheimer (*1, 2*) has made some interesting observations on *Sympherobius amicus* Navas in Palestine. This predator is admirably suited to its habitat and is remarkably effective. Unlike the California species, it has no recorded parasites. It has eight generations, the same as its host, and the average lot of 250 or more eggs usually produces 40 per cent or more of that number of adults.

There are several known parasites on Sympherobius in California, all of them chalcids. Records from the Pasadena laboratory notes taken from 1915 to 1918 show that *Dibrachys daphne* Girault was bred from *S. barberi* and *S. californicus*, and *Dibrachys boucheanus* Ratzeburg from *S. californicus;* there is also a very doubtful record of *Tomocera californica* Howard from *S. californicus*. From *S. angustus* two species of Isodromus were bred, *I. niger* Ashmead and *I. iceryae* Howard, and these parasites also attacked one of the green lacewings (Fig. 65). In spite of this interference by hymenopterous parasites, the brown lace-

wings are always present around mealybug colonies and are sometimes an evident factor in control.

The green lacewings, represented by three species of Chrysopa in Cali-

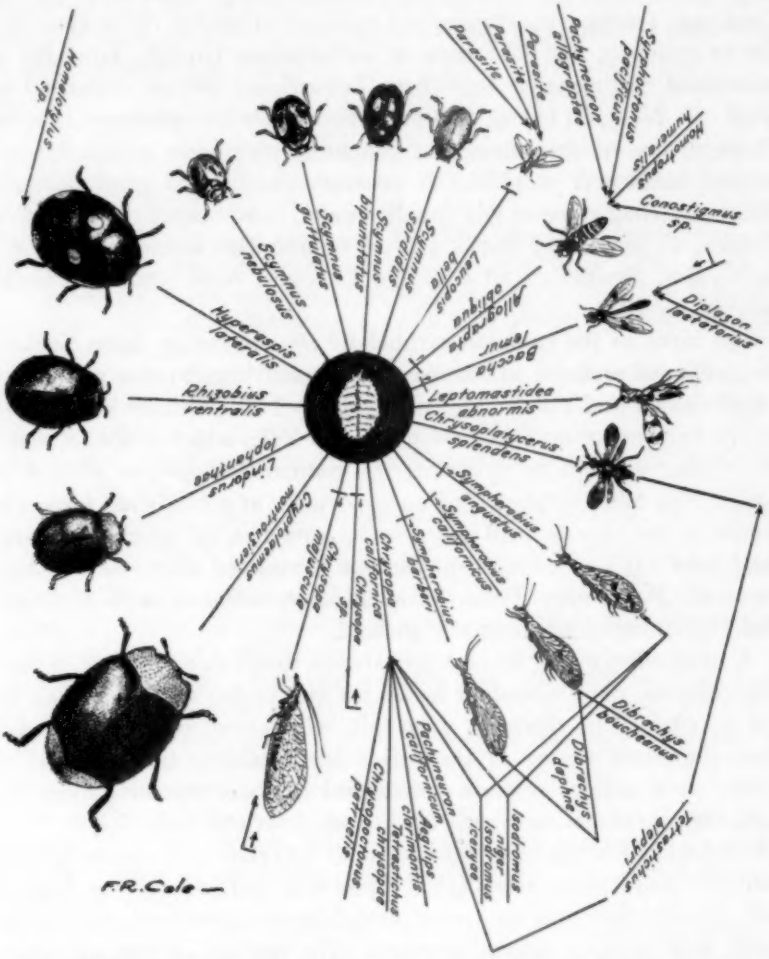

Fig. 65.—The figures of the coccinellid beetles are all drawn to a scale, the largest, *Cryptolaemus montrouzieri*, being actually about 3.5 mm. in length. The other insects figured are mostly on a smaller scale, the cross lines and arrows indicating the length if translated into the scale used for the beetles.

fornia (*20*) show evidence of potential efficiency, but there is too much parasitism by Hymenoptera. The feeding rates on all three species

were recorded at the Pasadena laboratory, and will be given in a later more complete paper. The commonest species is *Chrysopa californica* Coquillett (*20*) and from this no less than six parasites were bred: *Isodromus niger, I. iceryae* (common), *Chrysopoctonus patruelis* Cushman, *Tetrastichus chrysopae* Crawford, *Aegialips clarimontis* Kieffer (a cynipid), and *Pachyneuron californicum* Girault; from the last mentioned the common secondary *Tetrastichus blepyri* Ashmead was bred. *T. blepyri* (*18*) is also parasitic on *Chrysoplatycerus splendens* Howard, one of the introduced primaries previously mentioned, so a natural balance is possible. A general collection of green lacewings about mealybug colonies will usually reveal, in addition to *Chrysopa californica, C. majuscula* Banks and an undescribed species very near *C. californica.* Studies of all stages of Chrysopa were made at Pasadena in 1915 to 1918.

The larva of the common syrphid fly *Baccha lemur* Osten Sacken is an occasional predator in colonies of the mealybug, but the numbers are usually small and the feeding rate is low. This predator is parasitized by the hymenopteron *Diplazon laetatorius* Fab., which is also a parasite of another syrphid fly predator, the common *Allograpta obliqua* Say (*10*). This other syrphid is of no importance as a mealybug feeder, and would in any case be held down by its parasites, of which there are at least four (*10*) in addition to the one mentioned above—*Homotropus humeralis* Provancher, *Conostigmus* sp., *Syrphoctonus pacificus* Cresson, and *Pachyneuron allograptae* Ashmead.

A small silvery gray fly is nearly always found as a predator in mealybug colonies, more abundant about the citrophilus mealybug than with the *P. citri.* This dipteron, *Leucopis bella* Loew, was considered the most important enemy of the citrophilus mealybug back in 1917 and 1918. It is still a factor in the control of the citrus mealybug. Two unnamed parasites have been bred from *Leucopis bella.*

Woglum and Neüls (*21*) demonstrated the relation of ants to mealybug control about sixteen years ago. These ants, particularly the Argentine ant, not only distribute the young mealybugs on citrus trees, but also keep away most of their natural enemies. The method of keeping ants out of the citrus trees has been discussed in various papers (*22, 23*); suffice it to say that banding with sticky tree-banding material is usually effective, allowing the predators to work on the mealybug colonies unmolested.

SUMMARY.—In summing up the various factors in the natural control of *Pseudococcus citri,* it may be noted that the unimportant *Chryso-*

platycerus splendens is the only actually specific enemy, although *Leptomastidea abnormis* is nearly so, and *Sympherobius californicus* and *S. barberi* are perhaps 75 per cent confined to this host. This means that the insect enemies are not concentrated in their attack, but it also means that the reserve food of other hosts will keep predators and parasites alive when the citrus mealybug is scarce.

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FARM MACHINERY IN RELATION TO INSECT PEST CONTROL

By E. O. ESSIG, *University of California*

ABSTRACT

Regular farm equipment used in plowing, planting, cultivating, and harvesting and special machinery employed in irrigating, leveling, and many other farming practices may contribute considerably in reducing and even in controlling certain insect pests which may be present on the plants, in the stems or stubble, in the seeds or tubers, and in the soil.

Many attachments may also be used on such machinery for the express purpose of destroying insects.

Up-to-date modern economic entomology is a many-sided profession. It not only embraces a thorough knowledge of insects, but a considerable amount of intimate information regarding botany, chemistry, and engineering. The relation of farm machinery to insect pest control is becoming increasingly important. This is due to the fact that agricultural engineers are turning their attention to these problems and we are no longer entirely dependent upon the private inventor and manufacturer to fulfill such needs.

There are many insect problems the solutions of which lie in good and timely farm practices and the importance of such practices cannot be overestimated in the present stress of economic conditions. One of the fortunate aspects of such pest control is that the methods employed are also responsible for an increase in yield and a bettering

of the quality of the crop. Thus the most important factor in keeping down such pests as red spiders and thrips is maintaining proper food and moisture conditions in the soil to produce vigorous plants. Such conditions are difficult to secure under dry farming methods but thorough cultivation with proper equipment may greatly aid in conserving the precious moisture which nature gives in sparing quantities. Subsoiling and summer fallow also make their contributions. Irrigated lands often suffer for water because of the character of the soil and improper methods of irrigation. In such cases insects too frequently prove the inadequacy of the practices being followed.

A poorly prepared seed bed often delays germination of potatoes, beans, corn, wheat, barley, and other crops, and affords an opportunity for wireworms, root maggots, cutworms, and other soil infesting insects, to destroy the seeds or the young plants, which might have outgrown their attacks.

Certain types of pruning may open up the trees so as to make it impossible for certain insects to become destructive thereon.

Flooding during the winter has been an economic practice in controlling the garden centipede in the asparagus fields of the delta region, whereas the application of carbon disulfide emulsion has afforded control in greenhouses.

Timing the cutting of the alfalfa hay has a very important effect upon reducing the numbers of alfalfa weevil larvae in a field and close and clean cutting of the crop is also an important factor.

Hilling potatoes may be the determining factor in producing a crop free from the very injurious larvae of the potato tuber moth. Or digging them at the proper time may mean the difference between a clean and an infested crop. Even the thoroughness of removing the tubers from the soil has an important bearing in reducing the seriousness of the attacks of this particular potato pest.

In the recent ten million dollar European corn borer campaign, it was found that certain farm practices could be made far more effective than any other measures of control. Plowing under the corn refuse and other plant debris and the use of huskers and shredders showed the best results and are now generally recommended as the only economically effective methods of dealing with this serious pest.

Burning alfalfa fields for the destruction and control of weeds may also have an important bearing on the insect populations which may be present in the fields at the time.

Many other examples may be cited to show the importance and effectiveness of farm practices in connection with the control of insect

pests. All of these practices depend upon machinery for their execution—the better the implements the more effective the results.

Of course the use of certain specialized equipment such as sprayers, dusters, fumigators, and other devices, play a much more important part in the control of insect pests, but this paper is excluding them in order to emphasize the value of ordinary cultural practices and attendant machinery for a similar purpose.

Agriculture has also reached the stage of specialization which has necessitated mental as well as physical alertness. The growing of a particular crop has become a highly developed art involving a thorough knowledge of many important items. As in all scientific fields, equipment is one of the very important factors which determines success or failure. And I have a feeling that few farmers are aware of the significance of sound cultural practices in relation to the many and varied insect problems which constantly beset agriculture in all its complicated aspects.

Plowing is a necessity in all kinds of farming but the difference between a one-horse plow and a giant tractor beet plow is just one illustration of the many that might be called to mind. In regard to insect pests, plowing has some considerable significance. Deep plowing, in turning under infested plants and stubble, is highly important in connection with the control of the European corn borer, as already pointed out, the Hessian fly, wheat-stem sawfly, wheat jointworm, the larger corn-stalk borer, sod webworms, cotton boll weevil, and many others. Plowing also has an important bearing in the elimination of trap crops, designed to attract insects; cover crops, which may harbor many destructive forms; summer fallow; and clean cultivation. The success of all of these practices is wholly dependent upon the character of the equipment used, therefore the more efficient the equipment the more effective will be the results in destroying the plant materials and the insects which are associated with them.

But plowing does not always satisfactorily complete the task. In many cases where the weeds, refuse, stubble, or cover crop have reached large proportions, it may be necessary to precede plowing with a thorough disking in order to adequately dispose of the materials underground. Or the character of the soil may make it advisable to follow plowing with disking, harrowing, rolling, or dragging. At any rate a first class job is essential. The use of many simple devices on plows, such as cutters, coulters, chains, etc., often play an important part in turning under all surface materials.

One rarely thinks of planting as having any bearing whatever on subsequent insect attacks, but it is certain that too shallow or too deep planting may result in delayed germination and give soil infesting insects such as wireworms, grubs, and maggots, an opportunity to seek out and destroy the seed before it has time to germinate. The quantity of seed sown may also determine the difference between success and failure in the crop. It is often necessary to use much more seed than a good stand requires—the surplus dedicated as an offering to the subterranean pests.

Cultivation naturally follows next. Not only is the removal of weeds often desirable to prevent feeding and breeding places for insects, but the actual stirring of the ground often destroys the larvae and more particularly the pupae of certain beetles and moths. The actual hilling of potatoes is an important practice in excluding the adult potato tuber moths from the soil and results in a much cleaner crop. Cultivation of alfalfa, in connection with the attacks of the alfalfa weevil in the Great Basin area, has proven to be particularly practical in destroying the larvae and pupae of the insect, and adds materially to the quantity and quality of the crop.

Morning glory, a prolific host of red spiders, is often a menace to certain deciduous orchards and vineyards and other weeds and plants employed as permanent ground covers or cover crops may act as reservoirs of thrips, aphids, caterpillars, and countless other destroyers of plant life. It is needless to call attention to the importance of adequate equipment coupled with the determination and endurance of the farmer to eliminate such waste.

Let us now briefly consider some of the methods and machinery used for harvesting the crop. In the case of many products timely and rapid removal from the field is essential to prevent insect contamination. A few examples will illustrate the point. In the case of beans where infestation may occur in the field at harvest time, it is essential to cut, dry, and thresh just as soon as possible. To allow the crop to remain standing one week longer than is absolutely necessary may result in complete infestation by the bean weevil. Improved cutters and combined harvesters have not only made it possible to accomplish these ends, but have also resulted in leaving but a very small proportion of the shelled seed in the field where it may be utilized by the insects for food during the winter.

In connection with the potato tuber moth situation, time and manner of harvesting play an important part. The adults are often very

abundant as the crop ripens and easily make their way around the bases of the dead tops to the tubers upon which they lay their eggs. They also oviposit freely at night on potatoes left exposed on the ground or in sacks in the fields over night. Therefore, the equipment which enables early and rapid removal of the potatoes from the field has a marked influence upon the cleanliness of the stored tubers. Such examples may be multiplied considerably.

Special farm equipment may also play an important part in insect pest control, such as:

1. Insecticide applicators attached to plows, cultivators, and seeders for treating soil-infesting insects.

2. Use of planters and seeders of various types for distributing poison baits to control grasshoppers, caterpillars, beetles, weevils, etc.

3. Light traps to attract and destroy night-flying moths, gnats, beetles, etc.

4. Special harvesting machinery for crushing the plants and thereby killing stem-infesting insects, which would otherwise hibernate in the dried product.

5. Burning equipment for destroying weeds and seeds may affect aphids, and similar insects present at the time.

6. Air sweepers attached to tractors or trucks for capturing flying insects such as the grape leafhopper.

7. For digging trenches and erecting barriers to trap or exclude non-flying grasshoppers, caterpillars, beetles and bugs which often invade cultivated areas in great numbers.

8. For constructing devices to enable flooding to control such a pest as the garden centipede in the asparagus fields of the Sacramento and San Joaquin delta regions.

9. The use of drags, rollers, scrapers, and ground levellers, for crushing insects which have been exposed by the preparation and cultivation of the soil.

10. Special screens to eliminate hibernating insects from products at the time of preparation for shipment. The screening of certain crops for such purposes is occasionally compulsory as in the case of screening potatoes in Idaho to eliminate Colorado potato beetles.

11. Overhead irrigation equipment may have a marked effect in reducing or even controlling such pests as red spiders and thrips, but might actually increase the attacks of aphids, coccids, and other orchard pests.

12. Hopperdozers and other insect catchers for capturing grasshoppers and cutworms in pastures and on forage crops.

INSECTS AND AGRICULTURE

By E. O. Essig, *University of California*

Abstract

Insects often find conditions more suitable for development under modern methods of crop selection and crop specialization than in their natural environment. Thus great areas of single crops have been important factors in the rise of present economic entomology. In order to maintain quality in crop production it is absolutely necessary to continue the present effective program of insect pest control.

Concerning insects and agriculture one often hears such remarks as:

(1. Insects are on the increase.

(2. They are becoming constantly more menacing and injurious to crops.

(3. They are far more difficult to control than in former years.

These assertions though often only casually made are worthy of serious consideration. Is it really true that entomological problems in these modern days are more acute and difficult than of fifty years ago?

The answers to these inquiries are to be found only in unfolding the multiple complexes in the remarkable development of agriculture during the past century. This development has progressed most rapidly in the new world and particularly in areas having a wide range of climatic and geographic features, such as are to be found in California.

It is to be remembered that Old World agriculture lacked most of the present day aspects of this great industry. Farming bore none of the modern ideas of specialization. Farms were small and widely separated; the crops diversified and often rotated; and only those were cultivated, which years or even ages of experience, had proved to be hardy in each particular region. Experimental agriculture was not yet born. There was no exchange of ideas or of plants. Under such conditions insect problems were reduced to a minimum and were accepted as an act of Providence.

The development of new and vast acres of lands revolutionized agriculture. Specialization and experimentation began. In this country potatoes, wheat, corn, apples, and other hardy crops, gradually occupied extensive areas in the central and northern sections whilst tobacco, cotton, rice, sugar cane, and other introduced crops, prevailed in the South. In addition to the staple crops new ones were introduced from the four corners of the world for trial and substitu-

tion, if found promising. Thus we now see vast contiguous acres devoted to a single crop. Who has not been impressed with the unending fields of corn in the great corn belt, or of wheat on the western prairies or of cotton in the South? What pride there is in the potato fields of Maine, the apples of New York, and the beans of Michigan.

California offers a splendid illustration of this new kind of agriculture. Without a single native crop, but with a vast area of untold wealth in soil and climate, it has developed a highly specialized and varied type of agriculture. No less than 180 different crops are produced commercially within the confines of the state. Through a gradual process of adaptation and economic conditions certain areas are largely given over to a single crop or to a horticultural variety. These special areas differ considerably in size but in them the orchards and fields are more or less continuous, without intervening natural or artificial barriers. One cannot traverse California without noting the continuity of many kinds of orchards, of grains and other cereals, vegetables, and forage crops, and countless other forms of plant life. It is not difficult to indicate on a map where each is produced in greatest quantities.

Without attempting to develop this subject further or to go into details regarding the various specializations in crops, which are so well known as to require no further discussion, let us consider the effect of all this in relation to insect pests.

It may seem remarkable to some to know that no cultivated crop is free from insect enemies. In fact practically everyone of them is heir to a score or more depredators and a few are the hosts of legions. Every part of the growing plant, as well as the harvested fruit, seeds, and even the products manufactured therefrom, are subject to infestation and to partial or complete destruction. Certain insects are restricted to specific small or large natural groups or families of plants, whereas others are omnivorous feeders and attack a great and extensive variety. All of the cultivated crops which have been passed down through many generations appear to have always been infested with certain insects and yet new pests invariably appear wherever these plants are introduced into new lands and at times the new invaders appear to be even more destructive than the older ones.

When wheat was introduced into North America by the early settlers, the first destructive pest noted along the middle Atlantic Seaboard was a European insect, the Angoumois grain moth, so

named from a Province in France. However, its injury was small indeed compared with the later inroads of the Hessian fly, another possible European immigrant, and the native chinch bug, both of which found ideal conditions in the extensive wheat fields of the United States and Canada. The potato remained comparatively free from serious insect pests until potato culture spread across the Mississippi River and extended up the Missouri River and Arkansas River valleys to the haunts of the then unknown Colorado potato beetle, which found the potato so superior to the native buffalo bur to its taste and development, that it soon became the most formidable pest of this crop and rapidly spread to every potato patch east of the Rocky Mountains. This rapid natural dispersal was possible because of the almost universal practice of producing potatoes on every farm. But the insect became an economic factor only in those areas where potatoes had become a specialty and were grown in commercial quantities.

Similar instances of the destructiveness of insects may be cited for every crop produced in this and every other country.

To be more specific let us examine the situation here in California.

As already intimated every commercial crop grown in California has been introduced from some other portion of North America, or from some foreign country. Because of our natural resources in soil and climate, it was assumed that plants from practically the entire temperate and subtropical regions of the world could be grown somewhere within the boundaries of the state and many truly tropical plants were also introduced. In the early days before much was known concerning the importance of the insect pests and the methods of transporting them from one region to another, all forms of plant life and insects were freely admitted into the state. And they arrived in every conceivable manner and in every imaginable form, literally from everywhere. This importation of insect pests began in 1769 when the Mission Fathers arrived at San Diego with seeds of cereals and beans infested with weevils. It caused no alarm whatever until almost exactly 100 years had passed when the cottony cushion scale and red scale, began to ravage the citrus and the black scale the olive and citrus orchards of southern California; and the grape phylloxera, the codling moth, and the San Jose scale to infest the vineyards and orchards of northern California. So sudden and severe were the attacks of these pests and so great the losses that immediate steps were undertaken to prevent the further introduction and spread of insect

pests in the state. In carrying out this program much has been accomplished, but we have not yet succeeded in eliminating our entomological problems.

In making a recent survey of the various major insect pests in the state, it was revealed that the greater numbers were of foreign origin. At least 227 different species are immigrants as against some 50 native species.

As a matter of fact the insect pests did not become evident until agriculture had made considerable headway toward specialization when it was both favorable and possible for them to sweep over an area with ease. Climatic conditions and natural barriers have been the only means of staying such dispersals. In view of our present system of agriculture as already described and the general absence of regular crop rotations of any kind, insects are able to become permanently fixed.

The mild even temperatures of the coast are favorable to certain pests, whereas the hot dry summers of the interior valleys favor others. The comparatively warm winters also enable many to persist in great numbers, which might otherwise be killed by snow and ice.

Even though agricultural conditions in California are favorable to insect pests, the latter by no means have a free hand. Pest control in all of its phases has reached a very high state of development here.

The use of fumigants, poison baits, poison sprays, dusts, and other insecticides supplemented by the employment of certain beneficial insect predators and parasites have been most effective and practical. Certain agricultural practices involving many crops have also served to reduce injuries by insects. The exclusion of new pests through quarantine and inspection and the actual eradication of newly established insects are all included in the program of pest control in this state.

There is no doubt but what insects have increased both in abundance and destructiveness during the past century. Their attacks are more regular and constant—and the decidedly higher standards now required for the marketing of fruit and vegetables make commercial control constantly more difficult and expensive.

Insect pests cannot reduce quantity without destroying quality so that in order to have food products of good quality the warfare against them must continue unabated.

A GENERAL METHOD FOR MEASURING INSECT POPULATIONS AND ITS APPLICATION IN EVALUATING RESULTS OF CODLING MOTH CONTROL

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ABSTRACT

A method of determining insect populations in the field is given which is applicable for many different insects and crops.

Results, expressed as per cent increase between the initial and end populations, are presented for codling moth control on walnuts over a period of five years.

Economic entomological literature is filled with references to control measures in which results are given as per cent insect injured fruit, or other portion of plant, in treated plots in contrast to nontreated plots. Such a method is often employed to express population trends over a period of years. Expression of results by this method especially when different years are under consideration is open to a number of gross errors as only the ratio of occupied to possible occupied host sites is given. As both the population of insects and the number of host sites i.e. yield, vary from year to year and plot to plot, per cent figures give only the ratio between these two variables.

An insect population is but seldom evenly distributed even when relatively small areas are under consideration. It is therefore evident that unless plots are duplicated a number of times or the initial population in each plot is known, end populations will not of themselves give an index of the results of the experiment. When both the initial and end populations are known, any shift in the population density can then be expressed as per cent increase of the population.

The following method, which was devised by the writer to determine field populations and shifts in populations of codling moth infesting walnuts, can be applied with but slight modifications to many different types of work. The percentage of worm injury for each orchard is obtained by cracking and counting the wormy nuts in 100 nuts from each load delivered to the packing house. As no culling is done on the ranches, this gives the per cent of the total crop worm injured for each orchard. The number of wormy nuts in each orchard is determined by multiplying the per cent wormy by the production. In the following tables this figure is given as pounds, but may be converted to individuals by multiplying by 41 (41 nuts = 1 lb.). This will give the number of codling moth in the orchard, as but one codling moth infests a nut in

this region. To obtain the arithmetic mean, M, of the per cent wormy of the orchards under consideration, the pounds of wormy nuts is summed and divided by the total production of the orchards concerned. To obtain the per cent increase in the population, the pounds wormy per acre for the year under consideration is divided by the pounds wormy per acre from the *same* orchards for the *previous* year. When this procedure is followed for two groups of orchards having different treatments, a comparison of the shifts of populations can be made. This determination considers the previous year as 100%, so for example an increase of 75% is to be read as an actual decrease of 25%. This manner of treatment is employed to make minus figures unnecessary.

The probable error of M is obtained in the following manner: M is subtracted from the per cent wormy of the individual orchards, giving a number called Δ, this number is squared to give all plus figures. Number of nuts cracked $\times \Delta^2$ gives a series of figures which are summed and used in determining the standard diviation δ.

$$\frac{\text{Summation nuts cracked} \times \Delta^2}{\text{Total number nuts cracked}} = \delta^2$$

$$\text{Probable error of M} = \frac{\delta \times .6745}{\sqrt{n-1}}$$

Where .6745 is a constant and n the number of orchards considered.

The probable error of the per cent increase in the population is obtained in the following manner:

$$\text{P.E.} = \pm 100 \sqrt{\frac{(A)^2}{(B)^2}\left[\left(\frac{a}{A}\right)^2 + \left(\frac{b}{B}\right)^2\right]}$$

Where $A \pm a$ = lbs. wormy in given year.

$B \pm b$ = lbs. wormy in previous year.

The assumption is made that $r = 0$, this being the correlation between the infestation in a given grove from one year to the next. However the heavier infestations in a given year tend to occur in the same groves as in the preceding year, which would give r a value greater than that assigned to it. This would reduce the probable error of the per cent, increase, hence the error is on the conservative side in assuming that the correlation is zero.[1]

[1] I wish to acknowledge my indebtedness to Dr. C. I. Bliss for calling my attention to this method of solving for the probable error of the per cent increase in the population.

TABLE 1. RECORD OF DUSTED ORCHARDS 1931

Orchards	Production in lbs.	Acres	Hundreds of nuts cracked	Wormy nuts found	Per cent wormy	Per cent wormy × production	Per cent wormy less M = Δ	Δ²	Δ² × hundreds of nuts cracked
1	7,330	15	4	45	11.25	824	+5.11	26.11	104.44
2	23,155	23.5	8	31	3.87	897	−2.27	5.15	41.20
3	8,103	22	5	47	9.40	762	+3.26	10.63	53.15
4	5,442	10	3	34	11.33	617	+5.19	26.94	80.77
5	6,850	26	4	38	9.50	651	+3.36	11.29	45.16
6	2,589	2	3	9	3.00	78	−3.14	9.86	38.58
7	8,473	18	3	11	3.67	311	−2.47	6.10	18.30
8	69,559	54	13	45	3.46	2,403	−2.68	7.18	93.34
9	50,219	55	9	33	3.67	1,842	−2.47	6.10	54.90
10	28,646	30	7	30	4.28	1,226	−1.86	3.46	24.22
11	21,850	45	7	58	8.27	1,811	+2.13	4.54	31.78
12	68,728	120	15	121	8.06	5,541	+1.92	3.69	55.35
13	962	6	2	4	2.00	19	−4.14	17.14	34.28
14	10,324	39	10	62	6.20	641	+0.06		
15	65,023	55	18	79	4.39	2,853	−1.75	3.06	55.08
16	37,798	35	16	72	4.50	1,701	−1.64	2.69	43.04
17	11,546	10	4	38	9.50	1,090	+3.36	11.29	45.16
18	26,459	38	10	59	5.90	1,561	−0.24	0.06	0.60
19	44,842	37	23	129	5.61	2,513	−0.53	0.28	6.44
20	15,683	14	5	41	8.20	1,289	+2.06	4.24	21.20
21	26,432	21	15	82	5.46	1,441	−0.68	0.46	6.90
22	31,959	38	8	79	9.88	3,159	+3.74	13.99	111.92
23	3,097	17	2	12	6.00	186	−0.14	0.02	0.04
24	34,798	27	10	20	2.00	697	−4.14	17.14	171.40
25	45,414	31	9	51	5.67	2,572	−0.47	0.22	1.98
26	97,190	62	26	271	10.40	10,110	+4.26	18.15	471.90
27	6,252	18	5	45	9.00	563	+2.86	8.18	40.90
28	14,882	20	7	54	7.71	1,148	+1.57	2.46	17.22
29	33,186	38	16	153	9.57	3,175	+3.43	11.76	188.16
30	5,266	10	2	17	8.50	448	+2.36	5.57	11.14
31	75,332	56	24	151	6.29	4,740	+0.15	0.02	0.48
32	26,839	18	7	45	6.43	1,730	+0.29	0.08	0.56
33	37,335	33	17	79	5.64	2,106	−0.50	0.25	3.50
34	20,964	45	12	60	5.00	1,049	−1.14	1.30	15.60
35	30,187	35	11	43	3.91	1,182	−2.23	4.97	54.67
36	16,653	22	9	29	3.22	537	−2.92	8.53	76.77
37	11,795	17	10	72	7.20	850	+1.06	1.12	11.20
38	38,029	43	13	97	7.46	2,838	+1.32	1.74	22.62
39	145,684	167	33	153	4.64	6,760	−1.50	2.25	74.25
40	21,160	25	6	44	7.33	1,551	+1.19	1.42	8.52
41	22,944	28	11	115	10.45	2,395	+4.31	18.58	204.38
42	32,036	29	11	49	4.45	1,426	−1.69	2.86	31.46
Total	1,291,015	1454.5	430			79,293			2372.56

$$M = 100\ \frac{79,293}{1,291,015} = 6.142\%$$

$$\frac{79,293}{1,454.5} = 54.52 \text{ lbs.}$$

$$\delta^2 = \frac{237,256}{43,000} = 5.51768$$

$$\delta = \sqrt{5.51768} = 2.3489$$

$$\frac{.00247 \times 1{,}291{,}015}{1454.5} = \pm 2.19 \text{ lbs.} \quad \text{P.E.} = \frac{2.3489 \times .6745}{\sqrt{41}} = \pm .247\%$$

Per cent wormy = $6.142 \pm .247$

Wormy lbs. per acre = 54.52 ± 2.19

TABLE 2. 1930 RECORD TO COMPARE WITH 1931 DUSTED ORCHARDS

Orchards	Production in lbs.	Acres	Hundreds of nuts cracked	Wormy nuts found	Per cent wormy	Per cent wormy × production	Per cent wormy less M = Δ	Δ²	Δ² × hundreds of nuts cracked
1	27,007	15	9	30	3.33	899	+1.69	2.86	25.74
2	77,132	23.5	17	16	0.94	724	—0.70	0.49	8.33
3	35,491	22	13	22	1.69	602	+0.05		
4	13,800	10	4	12	3.00	414	+1.36	1.85	7.40
5	36,190	26	6	20	3.33	1,207	+1.69	2.86	17.16
6	1,968	2	1	4	4.00	79	+2.36	5.57	5.57
7	22,998	18	4	10	2.50	575	+0.86	0.74	2.96
8	119,102	54	15	12	0.80	953	—0.84	0.71	10.65
9	67,440	55	12	22	1.83	1,233	+0.19	0.04	0.48
10	58,906	30	10	9	0.90	530	—0.74	0.55	5.50
11	63,384	45	9	20	2.22	1,403	+0.58	0.34	3.06
12	195,457	120	33	87	2.63	5,150	+0.99	0.98	32.34
13	686	6	2	3	1.50	10	—0.14	0.02	0.04
14	61,447	39	13	30	2.31	1,419	+0.67	0.45	5.85
15	116,718	55	22	23	1.05	1,226	—0.59	0.35	7.70
16	53,681	35	19	37	1.95	1,047	+0.31	0.10	1.90
17	10,283	10	6	19	3.16	325	+1.52	2.31	13.86
18	66,888	38	20	21	1.05	703	—0.59	0.35	7.00
19	78,832	37	22	30	1.36	1,072	—0.28	0.08	1.76
20	14,533	14	6	4	0.67	97	—0.97	0.94	5.64
21	32,861	21	12	16	1.33	436	—0.31	0.10	1.20
22	49,607	38	12	37	3.08	1,528	+1.44	2.07	24.84
23	20,042	17	6	6	1.00	200	—0.64	0.41	2.46
24	62,183	27	14	14	1.00	622	—0.64	0.41	5.74
25	22,388	31	7	5	0.71	159	—0.93	0.86	6.02
26	129,497	62	36	60	1.66	2,150	+0.02		
27	26,180	18	5	12	2.40	628	+0.76	0.58	2.90
28	27,718	20	5	11	2.20	610	+0.56	0.31	1.55
29	53,845	38	20	35	1.75	945	+0.11	0.01	0.20
30	12,481	10	5	17	3.40	425	+1.76	3.10	15.50
31	86,977	56	13	21	1.61	1,400	—0.03		
32	36,136	18	8	8	1.00	361	—0.64	0.41	3.28
33	62,348	33	14	20	1.43	891	—0.21	0.04	0.56
34	67,516	45	22	21	0.96	648	—0.68	0.46	10.12
35	59,639	35	12	16	1.33	793	—0.31	0.10	1.20
36	35,082	22	12	18	1.50	525	—0.14	0.02	0.24
37	22,994	17	11	28	2.54	584	+0.90	0.81	8.91
38	67,694	43	18	30	1.67	1,130	+0.03		
39	204,656	167	31	33	1.06	2,169	—0.58	0.34	10.54
40	46,419	25	9	9	1.00	464	—0.64	0.41	3.69
41	61,921	28	13	26	2.00	1,238	+0.36	0.13	1.69
42	38,077	29	12	32	2.67	1,017	+1.03	1.06	12.72
Total	2,348,204	1454.5	540			38,591			276.30

TABLE 3. SUMMARY OF THE EFFICIENCY OF CONTROL MEASURES 1927–1931

Year and treatment	Acres	Number orchards	Production in pounds	M	δ	Pounds wormy per acre	% increase in population previous year as 100%
1927—Not dusted	154	4	476,069	0.464±0.193	0.4969	14.35±5.96	164.4±86.5
Previous year	154	4	114,708	1.172±0.430	0.9723	8.73±2.82	
Dusted	95	4	241,753	0.695±0.167	0.4287	17.68±4.25	157.9±47.9
Previous year	95	4	69,840	1.524±0.282	0.7247	11.20±2.07	
1928—Not dusted	324¼	6	512,571	1.176±0.207	0.6871	18.54±3.27	122.0±38.0
Previous year	324¼	6	872,911	0.565±0.140	0.4633	15.20±3.77	
Dusted	100	2	210,297	0.855±0.320	0.0478	17.15± 6.74	64.6±35.5
Previous year	100	2	336,573	0.789±0.304	0.4501	26.56±10.22	
1929—Not dusted	771	16	1,899,546	1.156±0.159	0.9107	28.48±3.91	455.0±77.4
Previous year	771	16	1,149,887	0.420±0.039	0.2268	6.26±0.59	
Dusted	649¼	20	1,625,260	0.720±0.063	0.4068	18.02±1.61	101.9±11.3
Previous year	649¼	20	1,002,404	1.146±0.076	0.4938	17.69±1.17	
1930—Not dusted	813	19	1,371,378	1.495±0.109	0.6849	25.22±1.85	205.9±20.7
Previous year	817	19	2,145,112	0.467±0.032	0.2012	12.25±0.84	
Dusted	784½	18	1,034,627	1.245±0.130	0.7966	16.41±1.71	38.1± 5.0
Previous year	818½	18	1,716,117	1.775±0.115	0.7045	43.06±2.42	
1931—Not dusted	1003	33	677,965	7.093±0.443	3.7013	47.94±2.99	646.1±20.6
Previous year	1003	33	1,130,421	0.659±0.052	0.4376	7.42±0.59	
Dusted	1454½	42	1,291,015	6.142±0.247	2.3489	54.52±2.19	205.5±12.5
Previous year	1454½	42	2,348,204	1.643±0.075	0.7153	26.53±1.21	

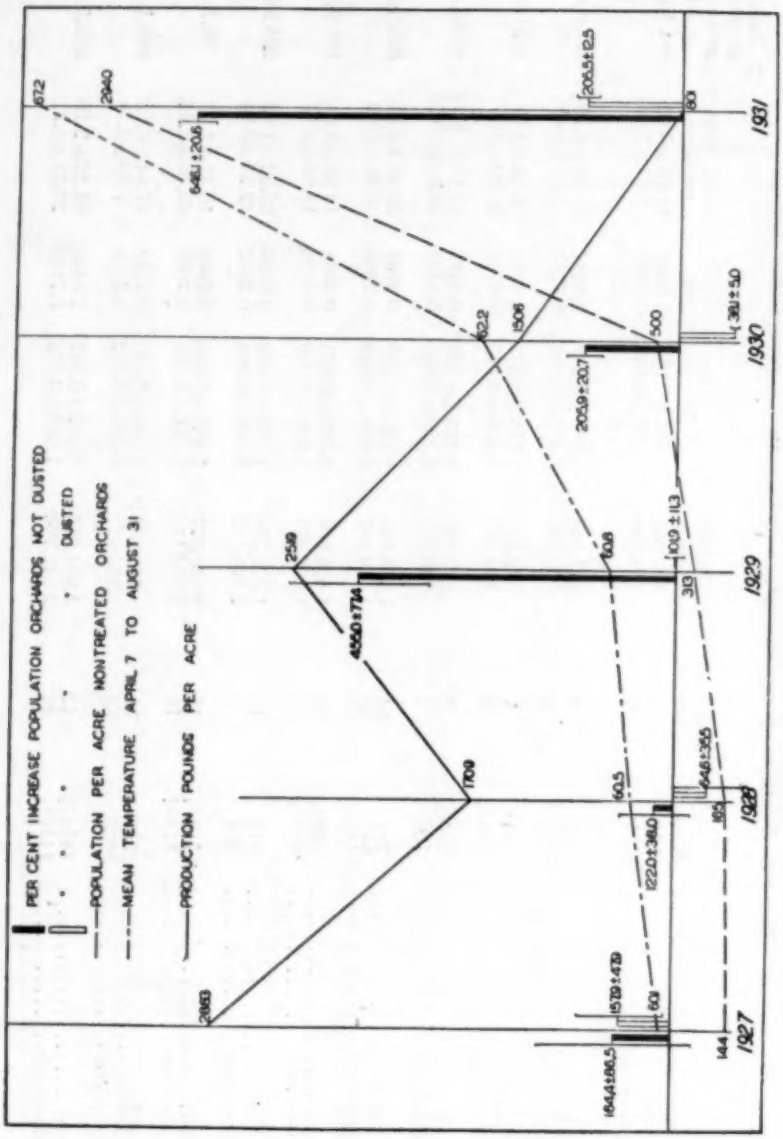

Fig. 66.—Graphic summary of codling moth control 1927–1931

$$M = 100\,\frac{38{,}591}{2{,}348{,}204} = 1.643\% \qquad \delta^2 = \frac{27{,}630}{54{,}000} = .51169$$

$$\frac{38{,}591}{1{,}454.5} = 26.53 \text{ lbs.} \qquad \delta = \sqrt{.51169} = .7153$$

$$\frac{.00075 \times 2{,}348{,}204}{1454.5} = \pm 1.21 \text{ lbs.} \qquad \text{P.E.} = \frac{.7153 \times .6745}{\sqrt{41}} = \pm .075\%$$

Per cent wormy = $1.643 \pm .075$

Wormy lbs. per acre = 26.53 ± 1.21

Per cent increase in lbs. 1931 over 1930 $= 100\,\frac{54.52}{26.53} = 205.5$

P.E. per cent increase =

$$\pm 100\sqrt{\frac{(54.52)^2}{(26.53)^2}\left[\left(\frac{2.19}{54.52}\right)^2 + \left(\frac{1.21}{26.53}\right)^2\right]} = \pm 12.5$$

Per cent increase in population, previous year taken as $100\% = 205.5 \pm 12.5$

An inspection of the preceding tables will demonstrate the erratic fluctuation of the production and the per cent of the crop wormy. As illustrated in Tables 1 and 2, it would be impossible to obtain an accurate idea of the relative density of population by inspecting the per cent wormy of the total crop.

This general method of determining population shifts can be used only when the population is not so dense that the actual increase is less than the potentional due to the insect being unable to find unoccupied host sites, i.e. saturation point being approached.

Explanation of line in chart marked "Population per acre nontreated orchards." Eight orchards totaling 346 acres were selected in which no control measures had ever been employed. The total pounds of wormy nuts produced each year was computed and multiplied by 41 giving the total population which was then reduced to population per acre. It is of interest to note the close correlation between this line and the mean summer temperatures obtained from readings every two hours.

CASEIN AMMONIA, A PRACTICAL EMULSIFYING AGENT FOR THE PREPARATION OF OIL EMULSIONS BY ORCHARDISTS

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ABSTRACT

A method is given for the preparation of insecticidal oil emulsions, using casein-ammonia as the emulsifying agent. Laboratory and large-scale tests establishing the practicability and satisfactory qualities of these homemade emulsions are described. Fruit growers in the Pacific Northwest have successfully made and used them in commercial quantity and have thereby effected considerable economy.

Seven or eight years ago, following the introduction of homemade oil emulsions into the Middle West (*1*), a considerable number of growers in the Pacific Northwest made their own emulsions for dormant spraying. The Government formula, calling for the use of soap as an emulsifier, could not be depended on, as the hard water in this region frequently broke down the emulsions made in this manner. Therefore, the Missouri formula (*2*, *3*), using casein-lime spreader, was employed. It was indicated by Regan (*5*) in 1926 that this attempt at economy by the growers was not altogether successful. However, the senior author was in the State of Washington during this period and he does not agree altogether with Regan's conclusion that fruit growers can not successfully make oil emulsions. Many of the failures were caused by trying to take unwarranted short cuts, by using old casein-lime spreader, in which the lime had changed to calcium carbonate, or by otherwise failing to follow simple directions. In fairness to the more careful growers, it must be said that many of them did make very satisfactory emulsions, and that a few of them have continued to do so to the present time. Most of them, however, after one attempt, preferred to purchase readymade emulsions, which in the meantime had become cheaper and more readily available.

The authors have witnessed, during the season just past, a return to the homemade emulsions on a basis which has been very successful, and they believe that the methods employed are worthy of notice by entomologists wherever oil sprays are used. Owing to the low price of fruit, growers were anxious to get their spraying done as economically as possible. Accordingly, a group of them in the Yakima Valley conferred with the senior author as to the advisability of making their own emulsions. It happened that a different formula, in

which the emulsifier consisted of casein and strong ammonia, had been used very successfully for three years by the members of the Western Cooperative Oil Spray Project. The senior author therefore suggested this formula to these growers, and both authors have made, under varying conditions, a number of tests of it.

This formula has proved to be very simple and effective, and it has several advantages over the casein-lime formula. The ingredients are cheaper, they do not deteriorate before use, they mix more readily with water, the resulting emulsion is thinner and hence more easily handled, and it may be kept for a number of weeks, as the ammonia acts as a preservative for the casein in addition to making it miscible with water. Credit for having first suggested this method should go to the late Anthony Spuler and to E. L. Green, formerly of the Washington Agricultural Experiment Station, who worked together on oil emulsions in 1928.[1] The original formula, which they never published, called for 6 pounds of casein and about 3½ pints of ammonia, to emulsify 100 gallons of oil, an emulsion containing 75 per cent of oil being made. Experiments by the authors and the practical experience of growers have shown the following proportions to be the most satisfactory:

Oil	100 gallons
Water	33 gallons
Casein (finely powdered)	3 pounds
Ammonia (28 per cent)	1 quart

Some growers have used only 2½ pounds of casein, and good emulsions have been made experimentally with 2 pounds or less, but the cost of the emulsifier is not great enough to warrant taking the chance of reducing it so much. This formula is based on the fact that the presence of ammonia causes the casein to mix, in a colloidal form, very thoroughly with the water. It has been very successfully used with oils for both dormant and summer spraying.

PRACTICAL EXPERIENCE.—Perhaps the best way to describe the method of making the emulsion is to relate how one or two growers proceed who have made large quantities.

Grower A has a 600-gallon portable spray outfit. He puts 132 gallons of water into it, adds 1 gallon of ammonia, and then slowly sifts in from 10 to 12 pounds of casein while the agitator is running. The oil comes in 50-gallon drums, and the grower has provided a 1½-inch pipe which reaches to the bottom of a drum through the large bung in one end. He connects this pipe to his spray pump by means of a

[1] E. L. Green. Correspondence with the writer.

piece of hose, and pumps the oil into the tank with the agitator running. The drum does not have to be lifted, and its contents can be emptied in less than two minutes. When 400 gallons of oil have been added in this manner, a suitable hose is attached to the overflow, and the mixture, which is already partially emulsified by the agitation it has received, is pumped through the overflow into empty drums, under a pressure of 250 pounds, and is ready for use. The whole operation takes about 1½ hours, and requires the services of two men.

Grower B has a 1,000-gallon stationary spray outfit. He usually emulsifies only 100 gallons of oil at a time, using the formula given above. The water, ammonia, and casein are put in with the agitator running, and then the oil is emptied from the drums through the large bung. When it has been added, the mixture is allowed to run through the pump at 250 pounds' pressure, and is sprayed through spray guns into drums. It is then emptied into the tank and again sprayed into drums, thus being completely pumped twice. The whole operation of making the 133 gallons of emulsion takes about one hour and is handled by one man.

From these two examples it is seen that the operation of making an emulsion may be continuous. The agitator should be running when the ammonia is put in, and the casein should be sifted in slowly to avoid lumps. It mixes with the ammoniated water immediately and the mixture does not have to stand. The oil should not be added too rapidly. There seems to be no need to pump the emulsion more than once if it has previously been thoroughly mixed by the agitator, and it may be simply pumped out through the overflow. Table 1 shows that the oil droplets in the emulsion made by grower A were the same size as those in the emulsion made by grower B, and that therefore the two emulsions were probably equally effective. These emulsions have been kept for six weeks or more without deterioration.

Small lots of 20 or 30 gallons for experimental use may be made in the ordinary 200-gallon power sprayer in the manner outlined above, and still smaller lots of a few quarts or gallons are successfully produced by stirring with an electric mixer or pumping with a bucket pump.

About the only danger of failure lies in getting a reversed, or water-in-oil, emulsion, which of course can not be diluted with water and therefore can not be used in that condition. The authors' experiments show that a water-in-oil emulsion usually results from too large a proportion of oil in the mixture, and that, once it has started

to form, it remains in this condition even though the proper quantity of water is added later. If the proportion of oil in the mixture is more than about 85 per cent, a water-in-oil emulsion results. This may be because with these proportions there is too little water to surround all of the oil droplets with a sufficiently thick film of water; the water then becomes the internal phase, surrounded by a much larger volume of oil. An oil-in-water emulsion may be reversed by simply adding oil while it is being stirred. The mixture gradually thickens until the oil content reaches about 87 per cent, when it becomes thin, owing to the formation of the other type of emulsion.

In practice, reversed emulsions apparently result from trying to make too small a quantity in a large tank. If the oil is added rapidly in a case of this sort, the agitator paddles may simply pull small quantities of water up into the oil and form a water-in-oil emulsion. This can be avoided by making a larger quantity or by adding the oil quite slowly until the paddles are well covered. A reversed emulsion need not be discarded, however. If allowed to stand for a time, it breaks down and the free oil may be drawn off and emulsified in the usual manner. Or, a new start may be made with the same quantity of water and emulsifier that was used the first time, and the reversed emulsion added in the same way that oil would be added. This will give an emulsion containing only 60 per cent of oil and due allowance for this should be made when it is diluted for spraying.

The cost of oil emulsions made in this manner is much less than that of the commercially prepared materials. A suitable, finely powdered casein has been available for 13 cents a pound. Ammonia, in 5-gallon lots or less, costs $1 a gallon. Under favorable conditions it does not require more than an hour's time to prepare 200 or 300 gallons of emulsion. Growers estimate the cost of operating the spray outfit at $1 per hour, and satisfactory labor can be obtained for not more than 25 cents per hour. The cost of emulsifying 100 gallons of oil, therefore, exclusive of the value of the oil itself, would be about as follows:

3 pounds of casein	$0.40
1 quart of ammonia	.25
2 men, one-half hour	.25
Use of sprayer, one-half hour	.50
	$1.40

This is not much over 1 cent per gallon of emulsion made, and even under unfavorable conditions, or if small lots are prepared, the cost

need not exceed 2 cents a gallon. This is cheaper than the Missouri formula. The cost of the emulsifying materials alone in the above formula is only 65 cents; the Missouri formula would call for about 12 pounds of casein-lime, which, at the usual price of 12½ cents a pound, would be $1.50.

During the last year growers have obtained oil for dormant use at 14 cents per gallon and for summer use at 21 cents per gallon. The cost of the finished emulsion made from these oils has thus been about 12 cents and 18 cents per gallon, respectively. Commercially prepared emulsions have cost 35 cents and 48 cents per gallon, respectively. The latter contain about 82 per cent of oil and the former contain only 75 per cent of oil, but even allowing for this difference there has been a saving of about 23 cents per gallon on the dormant emulsion and of about 28 cents per gallon on the summer emulsion. The oil used by the growers for dormant spraying has a Saybolt viscosity of about 105 seconds and an unsulphonated residue[3] of about 60 per cent. The oil used for summer spraying has a viscosity of 70 to 75 seconds and an unsulphonated residue[3] of 85 to 90 per cent. These specifications agree with those suggested by the Western Cooperative Oil Spray Project (*4*). A heavy Eastern oil, having a viscosity of 295 seconds, was also used experimentally. This made a very good emulsion, and is evidence that a wide range of oils may be emulsified in this manner.

In 1932 about 45,000 gallons of oil were emulsified by at least 25 different growers. This is sufficient to make about 60,000 gallons of emulsion, or enough to apply a dormant application and several summer applications to 30,000 or 40,000 trees. It is not yet possible to ascertain the total quantity of commercial emulsions sold in the Yakima Valley in 1932, but in 1931 about 725,000 gallons were sold, so that the quantity of emulsion made probably represents more than 8 per cent of the total used. These figures are given to indicate that the statements in this paper are based upon a considerable amount of practical experience. Only two or three growers had any serious difficulty with this formula. One of these failed because he attempted to use casein spreader in place of casein. The others got reversed emulsions, owing probably to an attempt to make too small a quantity of emulsion in a large tank. As these growers were able to reclaim the oil in the reversed emulsions, the loss was very small.

[3]Determined by method 70.5, employed 37 N sulphuric acid and temperature of 100°C. This method is used by the oil companies in California.

The authors are fully aware that growers purchasing oil emulsions from reliable manufacturers may obtain, at no extra cost, considerable service and advice regarding spraying. This is very valuable to many growers, and the authors would be opposed to making a blanket recommendation that all growers attempt to make their own emulsions. However, there are many growers to whom the information supplied by the manufacturers is not worth what it costs, and there seems to be no reason why such growers should not avoid this extra expense.

EXPERIMENTAL WORK.—Experiments were made with several emulsifiers, including milk powder, blood albumin, glyceryl oleate, ammonium linoleate, and lead arsenate. None of these was as good as the casein-ammonia. The milk powder and blood albumin emulsions broke down in a few days, apparently from decomposition of the emulsifier. The addition of ammonia corrected this to some extent. Milk powder is cheaper than casein, but blood albumin costs more. Glyceryl oleate and ammonium linoleate made very good emulsions, but are open to the same objection as is soap; hard water broke these emulsions readily, and even the addition of lead arsenate resulted in some separation of oil. The emulsion made with lead arsenate contained very large oil droplets, and these separated out readily when it was diluted. The average size of the oil droplets in all the emulsions examined is given in Table 1. The oil in these emulsions was of the type used for summer spraying.

The oil droplets in the homemade emulsions averaged three times the size of those in the commercially prepared emulsions, the average diameter of the former being 12 microns, and of the latter, 4 microns. Swingle and Snapp (*6*, Table 10), have shown that this difference should not significantly alter the toxicity to the San Jose scale, and the writers' experiments with codling moth eggs do not show any difference in the effect on them. The smaller oil droplets are necessary in an emulsion that is to be shipped and kept for several months, as such an emulsion must be quite stable, but they are not necessary in an emulsion that is to be used by the man who makes it. The homemade emulsions have not caused any more injury than the commercial materials, although they have been quite extensively used, not only by growers, but also by a number of investigators working on the Western Cooperative Oil Spray Project. Either type, if improperly used, may injure fruit trees.

The junior author has examined the deposit of oil left on apples and on glass plates by the two types of emulsion, and he finds that

the homemade emulsion leaves about the same quantity of oil as do the commercial materials. By means of the Gutzeit method he has also determined the quantity of arsenic deposited on apples by lead arsenate applied in combination with various oil emulsions. Samples of apples having equal weights and uniform size were used, and the

TABLE 1. AVERAGE SIZE OF OIL DROPLETS IN VARIOUS LUBRICATING-OIL EMULSIONS

Emulsion	Average diameter of oil droplets *Microns*
Commercial	
Brand A	4
Brand B	4
Brand C	4
Brand D	4
Made by growers	
A	12
B	12
C	12
Experimental[1]	
Casein, 6 pounds (in ammonia)	16
Casein, 3 pounds (in ammonia)	16
Casein, 1.5 pounds (in ammonia)	19
Blood albumin, 6 pounds	23
Milk powder, 6 pounds	40
Glyceryl oleate, 6 pounds	27
Ammonium linoleate, 6 pounds	7
Lead arsenate, 200 pounds	165

[1]Made with small electric mixer. Quantities of emulsifiers given are for 100 gallons of oil.

spraying was very carefully done. Lead arsenate was used alone, at 1 pound to 50 gallons of water, and at the same dilution in combination with the homemade emulsion and with four brands of commercially prepared emulsions. The dilute emulsion contained 0.75 per cent of oil in each case. The quantities of arsenic found were as follows:

	Grain per pound
Lead arsenate alone	0.068
Lead arsenate with homemade emulsion	.072
Lead arsenate with commercial emulsion (average of four brands)	.071

It is apparent that the homemade emulsion leaves a sufficient residue of lead arsenate. All these tests indicate that there is no objection to using the homemade material.

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THE INFLUENCE OF TEMPERATURE ON THE TOXICITY OF CARBON DISULPHIDE TO WIREWORMS[1]

By E. W. JONES, *formerly Assistant in Economic Entomology, University of Minnesota*

ABSTRACT

The relation of temperature to the toxicity of a soil fumigant for wireworms has been shown by means of a diagram. A study was made of the toxicity of carbon disulphide to wireworms at various temperatures when other factors, such as diffusion and adsorption have been eliminated.

The relation of temperature to toxicity has been determined by a method in which median lethal concentrations were the basis of comparison.

The results show that the median lethal concentration of carbon disulphide increases with a decrease in temperature. For every ten degree drop in temperature the concentration is approxmately doubled.

A review of the literature brings to our attention the multiplicity of factors affecting the efficiency of a soil fumigant. The extensive studies of soil from an insecticidal viewpoint, made by Marion (1877), Gastine and Couanon (1884), Blakeslee (1919), DeOng (1917), Leach (1920), Fleming (1923, 1925, 1928) and others, have shown the close relationship existing between the soil composition and condition and the effectiveness of the compound. Of all the physical factors concerned with the toxicity of a soil fumigant, temperature plays a leading role. The relation of temperature to the network of factors influencing the toxicity of a soil fumigant is presented in the diagram (Fig. 67).

Temperature is a factor influencing the physiology and activity of the insect, in turn influencing the rate at which the fumigant takes effect. Likewise, temperature, as it affects the physical processes of fumigated soil, is of chief importance as a factor in limiting the amount of chemical available as a fumigant. This availabilty of

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fumigant in the soil is in turn a factor in the toxicity of the fumigant. When temperature is lowered there is an increase in absorption and adsorption while, at the same time, loss of water from the soil and the diffusion of the gas is decreased.

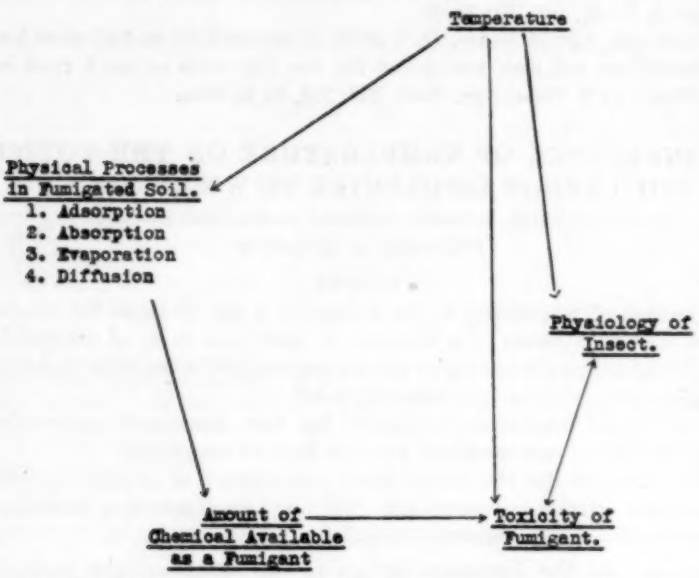

Fig. 67.—Diagram of the role of temperature in soil fumigation.

Only one phase of this relation between temperature and toxicity was chosen to be worked out in this study. Since very little information exists in literature on the relation of various temperatures to the toxicity of soil fumigants, it has been thought worth while to measure the toxicity of carbon disulphide to wireworms at various temperatures when the other factors of diffusion, adsorption, and so forth, have been eliminated. Later, it would be advisable to fumigate wireworms in the presence of soil.

The object of the present investigation was to study the toxicity of carbon disulphide over a series of temperatures (7°, 12°, 17°, 22°, 27°, and 32°C.). The method of determining relative toxicities consisted of measuring those concentrations which kill exactly 50 per cent of the test insects in a period of five hours. These were designated by Strand (1930) as the "5-hour median lethal concentrations." The experiments were performed in constant temperature and humidity chambers at University Farm, St. Paul, Minnesota.

Experimental Methods

Material.—In these experiments wireworms of the genus *Limonius* were used. These were taken from the soil in the summer of 1929 and placed in soil containers in the laboratory at room temperature (20°C.).

The carbon disulphide used was C. P. grade, obtained from the Central Scientific Company, Chicago, Illinois.

Apparatus.—The apparatus within which the insects were actually subjected to the action of the fumigant and which was used within the constant temperature and humidity cabinet consisted essentially of a rubber-stoppered six-liter Ehrlenmeyer flask. A number of flasks were fitted with paraffined rubber stoppers, and each one carefully calibrated. For each flask a special larval-chamber was prepared, which consisted of a small glass vial 30 x 80 mm. fitted up with a screen partition inserted to a depth of 10 mm. below the mouth of the vial.

Procedure.—The actual mode of operation was as follows: Each larval chamber (vial) was partially filled with 10 cc. of water, a necessary precaution to prevent the wireworms dying by desiccation. Twenty wireworms having been placed in each vial above the water, known concentrations of carbon disulphide were put into the six-liter flasks. This was effected by measuring out the liquid from carefully calibrated capillary pipettes each possessing a glass stop-cock. Vials containing the wireworms were then rapidly lowered to the bottom of the flasks by silk cord attached to each vial and the insects allowed to remain in the vapor for a period of five hours. During this time the flask remained in a constant temperature cabinet held at the temperature under investigation. In all cases, previous to fumigation, the larvae and flasks were held at the constant temperature for three hours.

In all experiments temperature of the cabinets was held constant by toluol-mercury thermostats and a hygrothermograph record was obtained. It was found in preliminary work that evaporation had a very important influence on longevity of the insect in a controlled environment out of the soil. By exposing the larvae over small vials of water this factor was controlled. It made no difference whether the relative humidity of the test flask was 30 per cent or 75 per cent. It is well to emphasize the point that the relative humidity was high about the immediate vicinity of the larvae and that the moisture condition thus resembled closely that of the normal soil environment of the wireworm.

After exposure, the larvae were taken out of the flasks and removed from the vials, then placed in closed containers with moist loam soil which were kept at room temperature (20°C.). The per-

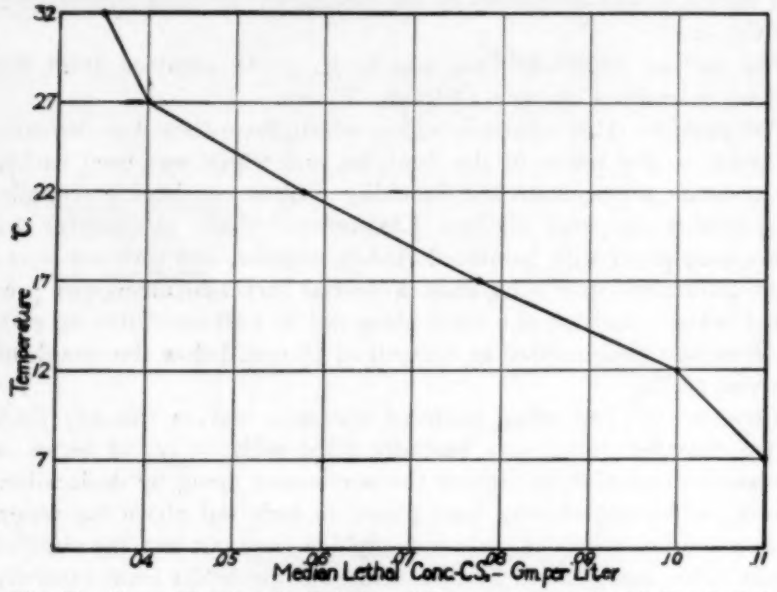

Fig. 68.—Curve Showing the Relation of Temperature to the Median Lethal Concentration of Carbon Disulphide for Wireworms.

centage of mortality of the fumigated insects was recorded 12 to 24 hours after the conclusion of the experiment and then checked on the second, third, fourth and fifth days. In several lots of twenty unfumigated insects held over the same periods after the 5 hour exposure to temperature in vials there was no mortality. Temperatures investigated were in no case fatal to checks.

The time at which mortality is recorded is important in these toxicity experiments with wireworms. It was noted that as the time interval of checking mortality was increased from 24 hours up to three to five days, the highest per cent of mortality occurred at about three days. However, the policy adhered to in this work was to take the 5-day per cent mortality as the final result of the toxicity of the fumigant.

A series of concentrations for each temperature was tested, in order to obtain progressive increases in the percentage of mortality from zero to near 100 per cent. The results expressed in percentage of mor-

tality have been plotted in the form of concentration-mortality curves. The median lethal concentration for each temperature was obtained by dropping an ordinate line from the 50 per cent point on the curve to the base line where the concentration was read directly.

Results of Experiments

The results with carbon disulphide and wireworms over a series of temperatures are presented in Table 1. The median lethal concentra-

Table 1. Median Lethal Concentration of Carbon Disulphide at Various Temperatures for Wireworms

CS_2 Conc. gm. per liter	Wireworms living	Wireworms dead	Mortality per cent	CS_2 Conc. gm. per liter	Wireworms Living	Wireworms Dead	Mortality per cent
	Temperature 7° C				Temperature 22° C		
.04	18	2	10	.02	20	0	0
.08	14	6	30	.04	18	2	10
.12	8	12	60	.06	9	11	55
.14	6	14	70	.08	2	18	90
.16	2	18	90	.12	0	20	100
.20	1	19	95	—			
.22	0	20	100	.057 M.L.C.			
—							
.11 M.L.C.							
	Temperature 12° C				Temperature 27° C		
.04	18	2	10	.02	20	0	0
.08	16	4	40	.035	13	7	35
.10	10	10	50	.04	10	10	50
.12	8	12	60	.05	5	15	75
.16	5	15	75	.06	4	16	80
.20	1	19	95	.08	0	20	100
.24	0	20	100	—			
—				.04 M.L.C.			
.10 M.L.C.							
	Temperature 17° C				Temperature 32° C		
.02	19	1	5	.02	19	1	5
.04	18	2	10	.03	13	7	35
.06	15	5	25	.04	5	15	75
.08	8	12	60	.05	2	18	90
.12	1	19	95	.06	0	20	100
.14	0	20	100	——			
—							
.076 M.L.C.				.035 M.L.C.			

tions and coefficients for carbon disulphide at six temperatures are given in Table 2 (Fig. 68). A temperature of 32°C. was used as the standard.

Table 2. Summary of Median Lethal Concentrations of Carbon Disulphide

Temperature °C	5 hr. M.L.C.—CS_2 gm. per liter	Temperature coefficient
32	0.035	1.0000
27	0.040	.8750
22	0.057	.6140
17	0.076	.4605
12	0.100	.3500
7	0.110	.3181

The influence of temperature on the median lethal concentration determined in this study of toxicity may be emphasized as follows:

A difference of 5 degrees temperature (1) from 32°C. to 27°C. increases the median lethal concentration only .005 gram carbon disulphide per liter. The successive five degree drops in temperature from 27°C. to 7°C. result in the following increases in the median lethal concentration: (2) 27°C. to 22°C. equals .017 gram or a difference three times as great as a drop from 32°C. to 27°C.; (3) 22°C. to 17°C. equals .019 gram or approximately a difference four times as great as the drop in (1); (4) 17°C. to 12°C. equals .024 gram or approximately five times as great as the drop in (1); (5) 12°C. to 7°C. equals .01 gram or a difference two times as great as (1) and less than that of any other of the successive five degree drops in temperature.

A difference of ten degrees (32°C. to 22°C.) resulted in an increase in the median lethal concentration of .022 gram per liter, and the next ten degree drop (22°C. to 12°C.) increased the M. L. C. .043 gram or approximately two times that of (32°C. to 22°C.).

ACKNOWLEDGMENTS.—The writer wishes to acknowledge his indebtedness to Dr. A. L. Strand for proposing this problem and for making helpful suggestions as the work progressed.

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FUMIGATION WITH PROPYLENE DICHLORIDE MIXTURE AGAINST *PYRAUSTA NUBILALIS* HUBN.[1]

By C. B. DIBBLE, *Department of Entomology, Michigan State College*

ABSTRACT

Propylene dichloride mixture used at the rate of two pounds to one hundred cubic feet of space gave a complete kill of European Corn Borer naturally established in sections of cornstalk. The shortest time for positive treatment was found to be twenty-four hours at temperatures from sixty degrees to seventy-eight degrees Fahrenheit, although many borers were killed in an eighteen-hour exposure. This information indicates the possibility of developing a method for treatment of materials (particularly truck-crop produce) prior to movement from infested to non-infested areas.

The number of host-plants attacked by the European Corn Borer (*Pyrausta nubilalis* Hubn.) introduces a serious problem in the movement of plant materials from infested to non-infested areas. This is particularly true with truck crop produce. Celery growers in Michigan were confronted with a quarantine problem in the summer of 1932, and the producers of greenhouse rhubarb face a similar possibility.

In a search for possible means of meeting this situation, preliminary tests were conducted to determine how corn borer larvae could be killed if present in truck crop produce. Contact insecticides as washes proved unsatisfactory, and fumigation was considered. This paper constitutes a report of preliminary work done with fumigants.

The most promising material seemed to be the non-inflammable mixture of propylene dichloride (90%) and carbon tetrachloride (10%). This is commonly sold under the trade name of "Dowfume". A preliminary test run for forty-four hours, using two pounds for each one-hundred cubic feet of space, killed all borers subjected to the treatment.

The strength at which the propylene dichloride mixture should be used was based on previous experiments, but the length of time required to secure a kill remained to be determined and experiments were planned on this basis. The trials were conducted with naturally established larvae of the European corn borer, by collecting cornstalks from infested fields. The infested cornstalks were cut into sections about a foot long, placed in a tight metal container, and fumigated. At the end of the fumigation the treated sections of corn-

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stalks were spread out on a table for aeration and later the stalks were dissected and the borers removed. Where the examinations were made immediately after the fumigation was completed, it was difficult to separate the living from the dead borers. Death is apparently due to stupefaction and partial paralysis. Where the final counts were delayed until several days after treatment there was little or no difficulty in separating living from dead borers. The treated borers were kept in a warm room and placed in a ventilated mailing tube with corrugated paper, as corn borer larvae will normally spin larval cocoons in this material. Their ability to perform this act after treatment was taken as an indication of survival. Time has not yet permitted a check of the possibility of their completing their life-cycles and reproducing.

Information as to the duration of the various treatments, temperatures, and the results noted are given in the following tabulation:

THE EFFECT OF PROPYLENE DICHLORIDE (MIXTURE) FUMIGATION ON *Pyrausta nubilalis*

Time	Temperature	Dead borers	Live borers	Total borers	Per cent killed	Remarks
44 hours	60–70	53	0	53	100	No life at end of treatment.
24 "	60–70	39	0	39	100	No indications of life to nine days.
24 "	60–70	26	0	26	100	Some life. No establishment to 12 days.
18 "	60–70	28	6	34	82.5	Some partly paralized. No establishment.
6 "	60–70	7	12	19	36.8	Active after six days. Some establishment in paper.
3 "	60–70	10	25	35	28.5	Active after six days. Some establishment in paper.
24 "	76–78	25	0	25	100	Some life. No establishment to twelve days.
18 "	76–78	8	18	26	30.8	One capable of locomotion. No establishment.

It is probable that some borers were killed by slight injuries in handling and counted as killed by the treatment. This has little influence on the data, for with the longer periods of time all borers were dead after treatment. Little difference is noticeable between the lower and the higher temperatures for the effective time periods, except that the paralysis was apparently more pronounced at the higher temperatures in some instances.

The preliminary treatment of forty-four hours gave a perfect kill. The twenty-four hour treatments were also satisfactory. The effect was not so immediately apparent, as some borers retained indications

of life for a short time, but could not perform ordinary life processes. This seems to be the shortest positive period of exposure in these tests, as all shorter periods failed in some instances to give total kills.

A period of eighteen hours exposure gave promising results, but many borers recovered from the stupefying effects of the treatment and some recovered their powers of locomotion. None established themselves, however, in the corrugated paper. It is possible that this exposure would be an entirely satisfactory treatment under all ordinary conditions as it is doubtful if any of these larvae would be able to reproduce. There is a reasonable doubt on this point, however, and the more positive action of the twenty-four hour treatment indicates its definite superiority for the slightly longer exposure.

All tests of less than eighteen hours duration were unsatisfactory. The borers came out of the treatment in a stupefied condition, but all uninjured larvae apparently recovered completely. Many larvae from both the three and six hour tests remained active at the end of six days and established themselves in the corrugated paper.

SUMMARY.—Propylene dichloride mixture, a non-inflammable fumigant, killed corn borer larvae in cornstalks. The material was used at the rate of two pounds to one-hundred cubic feet of space and, although an eighteen hour exposure killed many borers, a twenty-four hour exposure seems to be the shortest positive treatment under ordinary conditions.

A PRECISE METHOD FOR DETERMINING THE TOXICITY OF MIXED GASES TO INSECTS[1]

By R. M. JONES, *Investigator, Crop Protection Institute*

ABSTRACT

A precise method is described for determining the toxicity of mixtures of carbon dioxide and other gases to insects. The principle underlying the method is the introduction of the vapors of volatile fumigants into a partially evacuated fumigation flask, the amounts being measured by means of a mercury manometer. The fall of the mercury in the manometer is proportional to the con-

[1]This report constitutes a part of the research program of The Liquid Carbonic Corporation, Chicago, Ill., which is being conducted under the supervision of the Crop Protection Institute at Iowa State College, Ames, Iowa. The writer wishes to express his appreciation to the above organizations and to Dr. C. H. Richardson, Department of Zoology and Entomology, Iowa State College, for suggestions at various times.

centration of the gases in the fumigation flask. Air is then allowed to flow in until the mixture within the flask is reduced to atmospheric pressure. The details of the method are given and the apparatus is figured. The literature on methods for the determination of the toxicity of fumigants to insects is discussed briefly.

The use of mixed gases for controlling insect pests in stored products has increased rapidly during the past several years, largely as a result of certain observations made by Brinley and Baker (*3*), in 1927, and by Hazelhoff (*8* and *9*), in 1926 and 1928. The first investigators report that a small amount of methyl acetate seems to increase the toxicity of liquid hydrocyanic acid gas, by keeping open the spiracles of certain insects. Hazelhoff states that one may be able to accelerate the penetration of respiratory insecticides into the tracheal system by the addition of small amounts of carbon dioxide, thus increasing the effectiveness of a given concentration of a gas. Considerable experimental work along this line has been conducted by investigators in the U. S. Department of Agriculture (*2*, *5*, *6* and *7*).

Further investigations on gaseous mixtures by Jones and Kennedy (*11*), Mackie (*14*, *15* and *16*) and Jones (*12*) have shown that carbon dioxide may be used to advantage in reducing the inflammability of certain fumigants.

The use of carbon dioxide in admixture with fumigants therefore has a two-fold purpose; (1) to increase the effectiveness, and (2) to remove the fire-hazard of those which are inflammable and dangerous to use.

The method described in this paper was developed especially for investigating the toxicity of various fumigants in combination with carbon dioxide. A number of experiments have been completed, but will be reported in a separate publication.

METHODS PREVIOUSLY USED.—The methods for determining the relative toxicity of fumigants to insects have, in general, followed two separate lines; (1) the use of glass flasks as fumigating chambers, into which the fumigant is measured by means of small graduated pipettes, and (2) the use of flow meters to measure the concentration of the gaseous insecticide.

Method 1 referred to above has been employed by a number of workers (*4*, *10*, *18*, *19*, *20*, *21*, *25*, *26*, *27*, *28* and *29*) for conducting tests on the toxicities of various compounds to a variety of insects. These studies have for the most part, however, been confined to the use of single gases.

An improved fumigation flask designed recently by Dr. A. L.

Strand, of the Montana State College, was used by Lindgren and Shepard (*13*) in their studies on the influence of humidity on the effectiveness of certain fumigants against the eggs and adults of the confused flour beetle (*Tribolium confusum* Duv.). This apparatus consisted of a 6.2 liter Erlenmeyer flask, closed by a ground glass fitting. Two tubes provided with stopcocks were fused into the glass stopper. The one through which the fumigants were introduced projected a relatively short distance into the flask. The other tube reached nearly to the bottom, thereby increasing ventilation when the flask was flushed by a stream of air. The fumigants (chloropicrin, ethylene oxide and carbon disulphide) were measured volumetrically with pipettes graduated to 0.01 cc.

The only references the writer has found in the literature describing a method for the use of mixed gases are those by Cotton and Young (*5*), Cotton (*4*) and Brinley and Baker (*3*). Brinley and Baker make use of the flow meter type of apparatus and their paper will not be discussed here. Cotton and Young state, "the carbon dioxide was run into the flasks first and allowed to stand a few minutes before the fumigant was added." No further description is given in regard to the technique used in measuring the quantities of carbon dioxide into the flasks.

The apparatus described by McClintock, Hamilton and Lowe (*17*), in 1911, is similar in principle to that discussed in this paper. A partial vacuum was drawn in a large bell jar by means of a suction pump, the pressure being recorded on an attached manometer. The compounds to be used in the tests were placed in a flat brass dish, over which was fitted an inverted glass funnel. Heat was then applied. When vaporization commenced a stopcock was opened and the vapors were allowed to enter the bell jar. The gases were introduced into the jar after the mercury in the manometer had reached a height of about 680 mm., and the vacuum was then reduced to atmospheric pressure by air.

The use of flow meters (Method 2) to measure the concentration of gaseous insecticides was apparently first advocated by Neifert and Garrison (*22*). This type of apparatus was later employed by Neifert, et al (*23*), Brinley and Baker (*3*), Allison (*1*) and Richardson and Haas (*24*) for investigations on the toxicities of various compounds.

Some of the methods referred to above for determining the relative toxicities of fumigants to insects are admirably suited to the use of single gases, with air as the component part. However, as the

review of the literature shows, no accurate method has been described for determining the toxicity of a combination of gases, particularly if one of the compounds is a liquid and the other is a gas at ordinary temperatures. Due to the increasing popularity of the carbon dioxide and fumigant mixtures for commercial use, it seems desirable at this time to place in the entomological literature a precise method for determining the toxicity of these mixed gases to insects.

DESCRIPTION OF APPARATUS.—In this type of apparatus, the depression of the manometer is used as a measure of the quantity of the fumigant in the balloon flask. The apparatus is first calibrated by breaking a number of small ampules containing different weighed amounts of the fumigants in the flask after the apparatus has been evacuated. The fumigants vaporize almost immediately in the partial vacuum, resulting in a definite depression of the mercury in the manometer. When plotted as milligrams of fumigant against manometer depression these experimental values assume a straight line. The fall of the mercury in the manometer necessary to represent the desired quantity of the fumigant is obtained by reading directly from the graph. As the volume of the flasks used was 5.73 liters, then 286.5 mg. (5.73×50) would be required to give a concentration of 50 mg. per liter. By reading across on the graph, one can readily determine the number of millimeters the mercury should fall to indicate the above quantity, which in the case of carbon disulphide would be 12.6 mm. The desired amount of the carbon dioxide is then admitted in a similar manner. The straight line graph for carbon dioxide was calculated from the carbon disulphide graph, by the difference in the respective molecular weights. The percentage of the gases in the flask may be determined by dividing the fall in millimeters of the mercury by the prevailing barometric pressure.

A diagrammatic sketch of the apparatus for determining the toxicity of mixed gases to insects is shown in Figure 69. The set-up consists of a 5 liter Pyrex balloon flask *A*, closed with a ground glass fitting *B*, and sealed with a very small amount of stopcock grease or DeKotinsky cement at *C* to make an air-tight joint. The flask arrangement is connected to the filling assembly by a ground glass joint at *D*. The fumigant is contained in the small 25 cc. flask *E*. Two glass tubes, *F* and *G*, were fused into the glass top of the flask. An insect cage of bolting cloth was attached to the shorter of the two tubes. This tube was closed off by a ground glass cap at *H*. A manometer was attached to the side tube *I*.

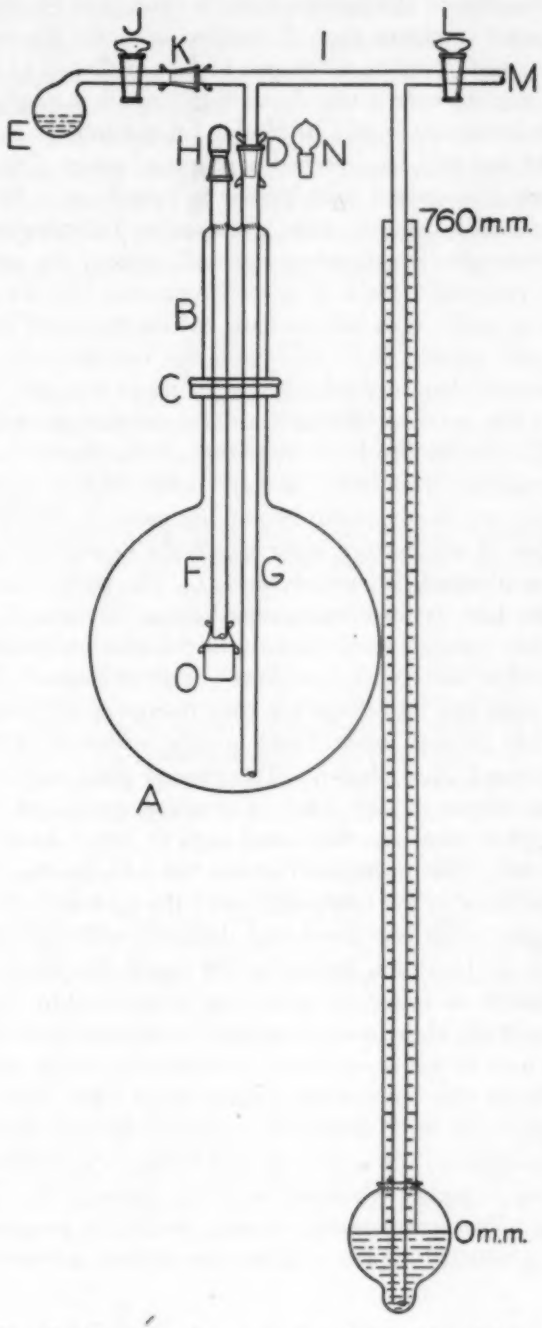

Fig. 69.—Diagram of apparatus used for determining the toxicity of mixed gases to insects.

PROCEDURE.—Before the balloon flask is connected to the filling assembly, the small fumigant flask *E* is filled with the compound to be tested, and is freed of air by either one of two methods; (1) by warming the flask slightly over a low flame until the air is displaced by the vapors of the fumigant, or (2) by closing off the tube at *D* and evacuating until the mercury has reached a height of about 700 mm., after which stopcock *J* is opened until the air is drawn out. Stopcock *J* is then closed, the flask containing the fumigant is disconnected at *K* and air is pulled through the side tubes until all traces of the vapors of the fumigant are removed. Flask *E* is then replaced. The second method was usually followed. The balloon flask is then connected to the filling assembly by the ground joint at *D* and the suction-pump is started. When the mercury has reached a height of about 600 mm. stopcock *L* is closed and the pressure tubing from the suction-pump is removed from tube *M*. The rubber hose from the carbon dioxide tank is then connected to tube *M*. Stopcock *J* is then opened slightly and the vapors of the fumigant are slowly admitted until the mercury has fallen the calculated number of millimeters, after which the desired amount of carbon dioxide is admitted through stopcock *L*. The rubber hose from the carbon dioxide tank is then disconnected from the tube *M*, and air is allowed to enter through stopcock *L* until the mixture within the large flask is reduced to atmospheric pressure. This stopcock is then closed. The balloon flask and its fittings are then disconnected from the filling assembly at the ground joint *D* and quickly stoppered with an interchangeable ground glass plug *N*. The ground glass cap at *H* is then removed and sample of 50 adult *Tribolium confusum* is dropped through the glass tube into the insect cage *O*, after which the cap is quickly replaced. This operation requires but an instant and introduces no appreciable error in the concentration of the gaseous mixture.

The apparatus described above was designed with the idea of using the vapors of the fumigant, instead of the liquid compound, but its use as such is limited to fumigants that have relatively low boiling points and correspondingly high vapor pressures. Fumigants with boiling points below 60°C. may be employed quite satisfactorily in the apparatus, but experience shows that compounds boiling above 70°C. do not have sufficient vapor pressure to be measured accurately by this method. However, the usefulness of the apparatus as a fumigating chamber for compounds boiling at higher temperatures is not impaired by the condition stated above. The liquid compound may readily be measured into the flasks with graduated pipettes, after the desired amount of carbon

dioxide has been admitted. Tests on *Tribolium confusum* with several low boiling compounds showed that the toxicity of a definite concentration of a fumigant was about the same whether the vapor or the liquid was measured into the flask.

The apparatus is somewhat costly, but this is offset by (1) the low cost of operation when using expensive compounds, and (2) the rapidity of making determinations. It is possible to have any reasonable number of flasks constructed to use with the one filling assembly, by having interchangeable ground joints at the connection *D*.

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INVESTIGATION OF NAPHTHALENE AS A FUMIGANT AGAINST THE PEACH TREE BORER, *AEGERIA EXITIOSA* SAY AND SOD INSECTS, A PROGRESS REPORT

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Abstract

Present status of investigations with naphthalene as a fumigant against peach tree borers and sod insects, is discussed.

During the past year the writer has carried on a number of tests with crude and refined naphthalene as a control for the peach tree borer, *A. exitiosa* Say, and with refined naphthalene as a control for various sod insects. Due to economic conditions this work has been discontinued and for fear it may not be resumed in the near future, this paper is submitted on the present status of the investigations.

Work with the Peach Tree Borer.—From the beginning of the work with toxic gases against the peach borer, naphthalene has been tested for its possible value. These tests showed naphthalene to be so slightly volatile under the conditions of use that toxic concentrations could not be secured with mound treatments. Blakeslee (*1*) and Peterson (*2*) both report naphthalene as ineffective. Apparently no injury to peach trees treated with naphthalene was observed by either worker.

During the summer of 1931, the writer began a series of tests on two year old Elberta and Hale trees. Crude and refined naphthalene were used at the rate of one-half ounce per tree. Three methods of mound application were used. In one series the materials were heaped directly about the bases of the trees. In the second series the material was scattered from the base of the tree to a distance about two inches away from the tree. In the third series, ring applications, one to two inches from the trees were made. All applications were covered over with a mound of earth. Treatments were left on for two weeks, four weeks, eight weeks and some were left on for almost a year.

Since no borers were present in the trees no control data was secured. It was determined, however, that applications made in contact with the bark cause gumming and dead areas in the bark. This was slight in the case of two weeks exposure but four and eight weeks exposure cause considerable injury. When applied in a ring one to two inches from the tree no injury developed from two, four and

eight weeks exposure and only slight injury after 11 months exposure. Under all conditions, the crude naphthalene appeared to be more toxic than the refined.

Since naphthalene volatilizes so slowly, it occurred to the writer that if naphthalene were placed about the base of the tree at the beginning of egg deposition or hatching and not mounded over, it might remain in position during the effective period and prevent the entry of the larvae into the trees. On August 13th, 1931, Elberta and Hale trees, two years old, were treated with crude and refined naphthalene at the rate of one-half ounce, one and two ounces per tree. The ground at the bases of the trees was not disturbed in any way by the treatment. The materials were simply heaped against the bases of the trees and left uncovered. Two weeks after treatment, an infestation of borers was secured by pinning cards, bearing about twenty borer eggs, on each of the trees. Later examination showed that 98% of the eggs had hatched.

No check was made until early in March, 1932, when a number of the trees were examined. The results are given in the following table.

TABLE SHOWING EFFECT OF NAPHTHALENE IN PREVENTING ENTRANCE OF PEACH BORER LARVAE

Variety	Naphthalene	Amount per tree	Number of borer eggs	Number of larvae found
Elberta	Refined	½ ounce	20	0
"	"	1 "	20	0
"	"	2 "	20	0
"	Crude	½ "	20	0
"	"	1 "	20	0
"	"	2 "	20	0
"	Check		22	3
"	"		27	5
Hale	Refined	½ ounce	20	0
"	"	1 "	20	1
"	"	2 "	20	0
"	Check		27	7
"	"		19	2

The control results appear promising but injury resulted from all treatments. This was shown by gumming and dead spots in the bark at and below the level of application.

Further work planned and under way but discontinued, included a study of the effects on older trees of direct applications; the amount of naphthalene necessary to last during the period of larval entry; the effect of diluents such as earth and sand on the toxicity of naphthalene to the borers and the trees; and the effect of diluents on bacterial decomposition of naphthalene. Since naphthalene costs less

than a third as much as paradichlorobenzene at present quotations and since surface applications would greatly reduce the labor cost. the matter seems well worth further investigation.

EFFECT OF NAPHTHALENE ON SOD AND ON SOD INSECTS.—It recently occurred to the writer that naphthalene might perhaps be effective in lawns and golf greens against such insects as webworms, cutworms, etc.

During the summer of 1932, preliminary tests were carried on to secure information on this question. Treating grass areas with pyrethrum solution showed no webworm infestation at Ligonier, Pa., where this work was carried on, but treatments were made to secure data on toxicity to other insects and to grass under various conditions.

A Kentucky blue grass lawn in fair condition was selected for treatment. It contained considerable white clover, some dandelion and plantain. Plots four feet square were marked off and treated with refined chip naphthalene at the rate of 200 pounds, 400 pounds and 600 pounds per acre. Three series of treatments were made. In one series the naphthalene was broadcast and left as it fell. In a second series it was broadcast and brushed in with a broom. In a third series it was broadcast and washed down with water by means of a sprinkling can. The weather on the day of treatment and for several days thereafter was noted as clear and hot, the temperature during the day running from 75 to 85 degrees.

An examination of the plots 72 hours after treatment showed no injury to the grass nor to the broad and narrow-leafed plantain. Dandelion leaves were scorched and the white clover was killed. Observations at intervals for 30 days after treatment showed no injury to the treated grass. It looked as well as or possibly a little better than the untreated areas though all areas suffered from drought. Dandelion quickly outgrew its injury but the white clover did not recover.

The day following the application of naphthalene, wireworms and cutworms were placed in small individual shell vials, the mouths of which were closed with cheesecloth. The rest of each vial was covered with tinfoil to cut down the effect of sunlight. At 11 A. M. with an air temperature of 80 degrees and a temperature of 81 degrees at the base of the grass, the vials with insects were laid on the ground at the base of the grass. Upon examination, three hours later, all of the larvae were dead in the 600 pound plots, 66% were dead in the 200 pound plots and all were alive and active in the checks. No

larvae were placed in the 400 pound plots. No recovery occurred. As between the different methods of application it was not determined that any method was superior to the others. It would appear then that broadcasting without brushing or washing down with water would be satisfactory.

In a recently cut-over hay field, a small plot was treated at the rate of 600 pounds per acre. Examination three days later showed many dead ants, Carabid and Staphylinid beetles and leaf-hoppers.

The method appears promising and worthy of further trial in webworm areas and on other species of grass.

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A NEW METHOD FOR COLLECTING SAMPLES OF INSECT POPULATIONS

By ORIN A. HILLS, *Junior Entomologist, U. S. Bureau of Entomology*

ABSTRACT

A new type of sampler for determining insect populations on wild and cultivated plants has been developed and is described. This sampler provides an accurate means of counting all the insects present on the plants growing on 1 square foot of ground. A suction pipette and a portable, electric, vacuum collector for collecting small insects from the sampler are also described.

A common method of sampling populations of insects on vegetation has been the "sweeping" method. In this a definite number of sweeps are taken over the plants with a standard-size insect net, and the results expressed in terms of the number of insects per sweep or per 50 or 100 sweeps. This method when used in population studies of the beet leafhopper has usually been supplemented in late fall and early spring by counts of the insects occurring per unit area. These counts are made by careful observance of the insects disturbed when examining the area on the hands and knees. Counts of this kind are possible only when host plants are small and when temperatures are low enough to cause the insects to become more or less sluggish. These methods have the disadvantage of producing results that are not directly comparable throughout the season. Also, temperature has a considerable effect on the activity of the insects, and other factors such as wind velocity and condition of the plants must be taken into consideration with the sweeping method.

At Hermiston, Oreg., studies of the beet leafhopper, *Eutettix tenellus* (Baker), and of the insects associated with it on both wild and cultivated hosts have been conducted as a part of the sugar-beet insect project of the Bureau of Entomology. Here populations of these insects are often so high that hand-and-knee counts are not possible, and sweeping is not practicable, owing to the small size of the plants and the comparative inactivity of the insects, due to low temperatures. The method herein described makes possible accurate counts of the insects on a square-foot basis whenever temperatures are high enough to cause slight activity. Thus counts from early spring, throughout the summer, and to late fall are directly comparable. Since the sampler covers only a single square foot, a number of samples must be taken in order to obtain an accurate average.

THE SQUARE-FOOT COUNTING CAGE.—The principal part of the equipment consists of a cylindrical cage mounted on a 4½-foot pitchfork handle (Pl. 40, Fig. 1). By means of the long handle the cage can be suddenly set in place over the plants. Since the cage must be set down forcibly so as to sink into the soil enough to provide an insect-tight seal, the frame of the cage must be very durable to stand the continual shock and yet light enough to facilitate easy handling.

The frame consists of two circular bands 13.56 inches in diameter (inclosing 1 square foot) connected by four 20-inch uprights welded to these bands. The top band is made of ⅛-inch by ¾-inch strap iron, the bottom of ⅛-inch by 1¾-inch iron. The lower edge of the bottom band is ground to a knife edge so that it will easily sink into the soil. About one-half inch down from the top edge of the bottom band small holes are drilled about one-half inch apart to permit sewing the cloth cover to the band.

The handle is attached to the lower band by means of a ⅜-inch bolt inserted into the end of the handle and through a hole in the band. The bolt is held securely in the band by a nut inside and one outside of the band. Experience has shown that an ordinary bolt will not serve here, as the ordinary bolt metal is soft and will bend easily, and also it tends to turn in the fork handle. This was overcome by using a square piece of key steel rounded and threaded on one end to receive the nuts. A wire brace from the top band to a screw eye in the handle greatly strengthens the cage.

The sides of the cage are covered with a good grade of sheeting. This material has been found most practical because of its durability, and at the same time it is thin enough to admit light. The top of the

cage is of canvas in which is sewed a piece of heavy transparent celluloid. This top is made removable, in order to facilitate counting when insects are inactive, by attaching the canvas to a light metal hoop which has been cut and the ends arranged to be drawn together with a thumb screw (*a*, Pl. 40, Fig. 1). The hoop, with the top at tached, can be clamped in place around the top band by tightening this screw. The bottom of the cage is of course left open, but is closed by the soil when the cage is in place.

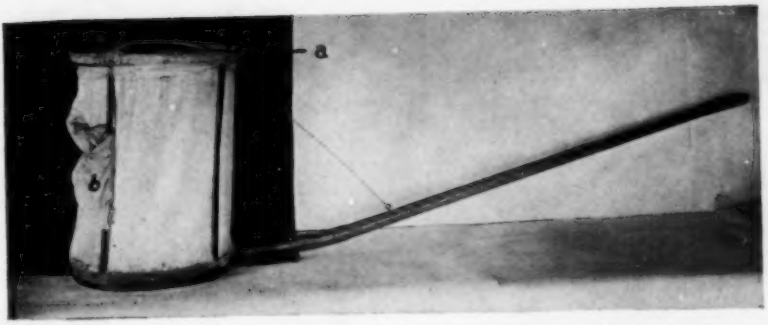
In the side of the cage opposite the handle a hole about 6 inches in diameter is cut and fitted with a sleeve about 1 foot long. The end of the sleeve is equipped with an elastic band. This sleeve permits the operator to insert one hand into the cage, and with the elastic band tight around the wrist there is no danger of the insects escaping. While the cage is being set in place the sleeve is tucked behind one of the iron uprights and so held shut (*b*, Pl. 40, Fig. 1). The celluloid top allows the operator to see into all parts of the cage.

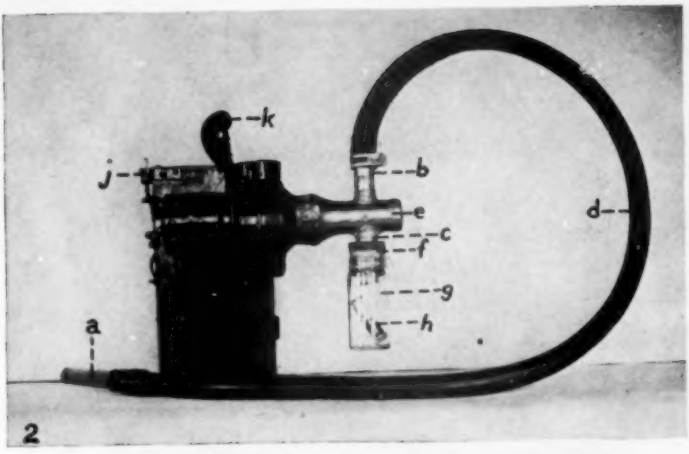
COUNTING METHODS.—If the cage is so placed over the plants that the sun is on the side opposite the sleeve the insects will congregate on this side of the cage. However, if an accurate count is to be made the insects must in some way be removed and, if very numerous, killed. This is done by one of two types of vacuum insect collectors. One is a modified pipette, the suction being provided by the operator's lungs. The other is an electric vacuum collector, the suction being supplied by a small motor-powered blower fan. The former type is used when the insects are few and temperatures are such that they are not very active, as in early spring and late fall. The electric vacuum collector is used during the warmer months when the insects are abundant and active.

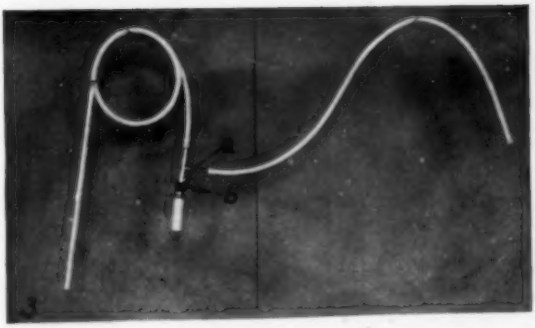
THE MODIFIED PIPETTE OR MCGINNIS COLLECTOR.—The suction collector described here is a modification of one first used by G. R. McGinnis[1] in 1923 for the collection of *E. tenellus* from breeding cages and is useful for removing insects from the cage described above when accurate counts are made of moderately small insects.

The apparatus consists of a **T** tube with rubber tubing attached for the conduction of air and insects (Pl. 40, Fig. 3). At the point *a* is a brass cloth screen of 40 meshes to the inch to prevent the insects from being drawn through the suction tube. The end of the **T** tube opposite the intake is fitted with a cork, *b*, to accommodate a 3-dram

[1]Temporary field assistant at the time.







1.—Square foot counting cage; 2.—Electric vacuum insect collector; 3.—Modified pipette or McGinnis collector.

homeopathic vial. If populations are low enough the insects in this vial may be counted alive; if not, they are easily transferred to a small cyanide jar. This collector should always be used with vial down.

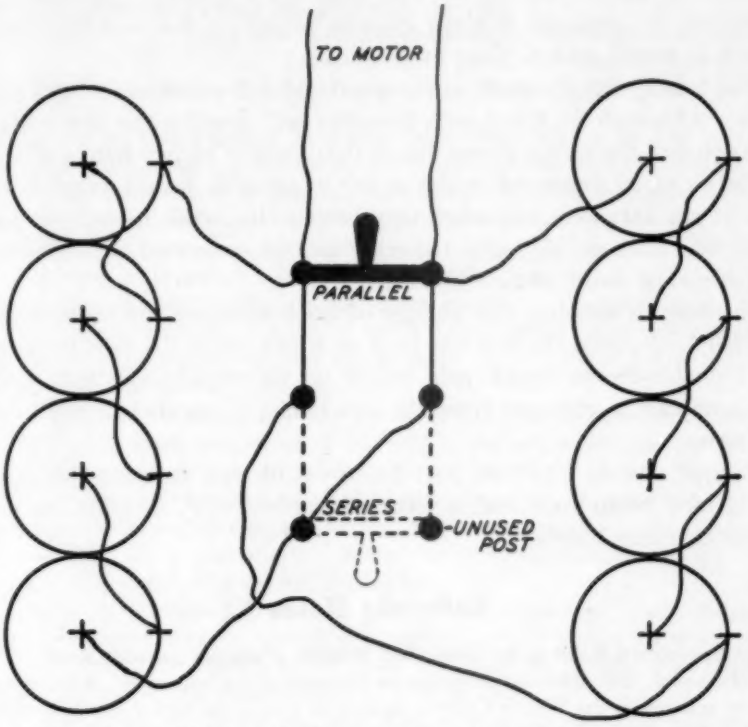


Fig. 70.—Diagram of hook-up for battery box used on electric vacuum collector.

THE ELECTRIC VACUUM COLLECTOR.—This apparatus has proved a most valuable aid in making counts of *E. tenellus* when populations are high. With it from 40 to 50 adults and twice as many nymphs have been removed from the cage in 5 minutes.

The motor and blower fan (painted black, Pl. 40, Fig. 2) were purchased assembled as they appear in the photograph. This assembly is intended for forced circulation in automobile heaters and is handled by dealers in automobile supplies. The nickle-plated apparatus soldered to the blower assembly works on the same principle as the McGinnis collector. The tubing used is thin, nickle-plated brass obtainable at hardware stores. Tubes *a*, *b*, *c*, and the rubber tube *d* are seven-eighths inch in diameter. The rubber tube is 4 feet long.

Passing through the horizontal tube *e* and connecting the ends of the tubes *b* and *c* is a screen tube of 40-mesh brass cloth. The large cork *f* is glued in place on the tube *c*. The container *g* is easily detached to remove or inspect the catch. The insects are killed by cyanide gas generated by granular calcium cyanide placed in the 3-dram vial *h*, which is closed with a piece of muslin.

The battery box *i* is made of ply-wood and will accommodate eight dry cells. Although four dry cells in series will develop the necessary 6 volts to pull the motor it was found that the use of two banks of four batteries each, connected to the motor in parallel, would lengthen the life of the batteries, and when they become too weak to pull the load with this hook-up all eight batteries can be connected in series and considerably more service obtained.

In order to simplify this change of hook-up when the batteries are partially exhausted the box has been so wired (Fig. 70) that by means of a double-throw, double-pole switch on the outside of the box, the hook-up can be changed from the two banks in parallel to eight cells in series.

A small switch, *j* (Pl. 40, Fig. 2), serves to start and stop the motor. A ¼-inch hemp rope and a piece of garden hose, *k*, make an adequate carrying handle.

Scientific Notes

An Unreported Habit of the Seed Corn Maggot, *Hylemyia cilicrura* Rond.—During December, 1931, while investigating an outbreak of the bean aphid, *Aphis rumicis* L., on spinach in the Winter Garden district of Texas, the writer received reports to the effect that the crop is very often seriously damaged by a bud-worm. Upon investigation a dipterous larva was found to be the form involved. Flies reared from larvae collected injuring the crop were determined as *Hylemyia cilicrura* Rond. by Dr. J. M. Aldrich of the U. S. National Museum.

Injury is caused by the larva infesting and damaging the immature unfolding leaves at the apex of the plant above the crown. Owing to this habit of attacking the host plant above ground, which, so far as can be ascertained, has not been reported heretofore, the pest is known locally as the "spinach bud-worm." Although plants injured are not destroyed outright, damaged crops are considered unfit for shipment because of the deformity produced. Plants having a loose spreading terminal growth seem to be less subject to attack than those having a compact terminal growth. According to the information obtained from several growers, the "bud-worm" injures spinach only during periods of rainy weather. Incidentally, under the same weather conditions, mildew, or "blue mold," very often infects and seriously damages the crop. The decay produced by this disease may be an influencing factor in causing this fly to depart from its normal habit of ovipositing in the soil and breeding on subterranean matter.

This same type of damage to spinach has been reported in the Walla Walla district of Washington by Mr. M. C. Lane. He reports, however, that no noticeable disease such as mildew or mold was observed in conjunction with the insect damage, and also that the damage appeared to be more severe in fields where heavy applications of barnyard manure had been made previous to planting.

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U. S. Department of Agriculture

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A Spray for Insect Control in Empty Grain Bins. Due to the low price offered for grain in 1931 and 1932, larger quantities than usual have been held in storage on farms and in elevators in Illinois. Some of this grain has been held for two or three years. This condition has resulted in a marked increase in stored grain insects in many instances.

A spray of eight per cent miscible oil and three pounds of lye to one hundred gallons of water applied to the empty grain bins has given good results as a clean-up treatment. A miscible oil of the type used for spraying dormant trees for scale is satisfactory for this purpose. Dendrol is the trade name of the oil that was used in these tests.

The spray should be applied until the walls and floor are thoroughly soaked. Enough spray must be applied to thoroughly wet all waste grain, chaff and dust that has not been removed from cracks and corners.

The addition of lye to the miscible oil spray improves the wetting and penetrating properties. This spray solution will enter cracks and wet dust and chaff readily. It is also effective against adult beetles which are difficult to wet and kill except with unemulsified oils.

If the spray is allowed to stand in pools on a painted floor it will soften the paint. The spray does not corrode metal if it is applied so that it dries in three or four hours. The caustic properties of the spray are rapidly neutralized by the CO_2 of the air and organic material such as chaff.

The foundation of the bin and any chaff or waste grain under or near the bin should also be thoroughly wetted. Caution should be used in spraying piles of waste grain containing a bushel or more as the water in the spray may cause the grain to heat.

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A New Strawberry Pest. On February 26, 1932, the writer received a message from a strawberry grower at Long Beach, Miss., advising him that insects were literally destroying his strawberries, particularly the ripe and nearly ripe fruit. The grower stated that fully 90 per cent of his ripe berries had to be thrown out or classed as culls on account of the holes in the fruit. An examination revealed the presence of an abundance of the black cutworm, *Agrotis ypsilon* Rott., some mole crickets, *Scapteriscus aculeatus* R. & H., sowbugs, and a small black tenebrionid beetle, *Crypticus obsoletus* (Say) (determined by E. A. Chapin) beneath nearly every plant. When the plants were disturbed or the soil beneath them

was stirred, the beetles, averaging from 5 to more than a dozen to a plant, would run in all directions. If the plants were handled carefully, the beetles would remain perfectly still beneath clods and loose soil and go unnoticed. The grower was of the opinion that the beetle was doing most of the damage, but the writer could not agree, since he had never before found this insect injuring strawberries.

After the cutworms and mole crickets had been controlled by spreading a poisoned bait among the infested plants, it was found that these beetles either refused to feed on the bait or were unaffected by it, and the injury continued. Further examination of the infested field by the writer, assisted by Mr. G. L. Phillips and the grower, disclosed a number of beetles feeding inside the ripe fruit, especially where care had been taken not to jar the fruit, thus causing the beetles to drop to the ground and conceal themselves beneath clods and elsewhere.

This beetle has since been found injuring strawberries in several fields throughout the season, but it was numerous only in the one field at Long Beach, which was near a large dairy barn. Some injury by the beetle was observed in other fields up to May 30. So far as known, this is the first record of injury to strawberries by this beetle.

M. M. HIGH, *Associate Entomologist, U. S. Bureau of Entomology*

Efficiency of Lubricating and Tar Oil Emulsions Against Scurfy Scale (*Chionaspis furfura* Fitch). Experiments conducted in the Hudson Valley in 1932 and 1933 as to the effectiveness of various strengths of lubricating oil emulsions and tar washes in controlling scurfy scale, indicate that both materials may be used efficiently. In 1932 a 4, 5 and 6 per cent lubricating oil emulsion (Diamond paraffin emulsified with Bordeaux mixture) was used, while in 1933 this treatment was used at 3 and 4 per cent, and a tar wash (Arbo) at 2, 4 and 6 per cent strengths. All sprays were applied in the spring while the trees were still dormant. The results obtained are given in the following table:

Treatment	Hatched egg masses	Killed egg masses	Masses killed, per cent
1932			
6% lubricating oil	117	1,634	93.31
5% lubricating oil	114	680	85.64
4% lubricating oil	91	805	89.84
Check	1,243	19	1.50
1933			
6% tar wash	29	811	96.55
4% tar wash	252	668	72.60
2% tar wash	133	302	69.43
4% lubricating oil	292	729	71.40
3% lubricating oil	453	407	47.33
Check	976	11	1.11

The above data were obtained after examinations of scales on check trees showed that hatching was complete. In both 1932 and 1933 the scurfy scale had completed hatching by the last of May. The egg masses counted were on branches taken at random from various positions on the trees. The egg masses which had hatched normally were distinguished by the presence of light-colored membranous eggshells, as contrasted with the dark, shriveled appearance of eggs killed by spray, and by the proximity of numerous young individuals. The number of eggs under

each egg mass varied from 7 to 83 with an average of about 40, and normally 98 per cent of the eggs hatch.

No noticeable injury to the trees resulted from the use of the tar washes. Bud development was delayed and a few buds were killed where the 5 and 6 per cent oil emulsion was used; this condition proved of little consequence, however, since the trees soon assumed a normal appearance.

L. E. AULL, and R. W. DEAN, *Vassar Laboratory of the N. Y. Agricultural Expt. Station*

The Relative Toxicity of Some Fluorine Compounds as Stomach Insecticides. In 1930 the senior author, now at the University of Minnesota, determined roughly the relative toxicity for the silkworm of a number of fluorine compounds prepared by the junior author. The leaf-sandwich method, described by Campbell and Filmer (Trans. IV Internat. Cong. Ent. Ithaca, 523–533. 1929) and modified by Campbell (Jour. Econ. Ent. 23: 357–370. 1930) was employed. In Table 1, each result is expressed as a median lethal dosage range within which lies the median lethal dose. The solubilities in water of the compounds tested were determined by the junior author (Indust. Eng. Chem. 20: 1195. 1928; *ibid.* 22: 886–889. 1930). These solubilities are listed in Table 1.

TABLE 1. FLUORINE COMPOUNDS, THEIR SOLUBILITIES IN WATER, AND MEDIAN LETHAL DOSES FOR FOURTH-INSTAR SILKWORMS[1]

Compound	Formula	Solubility at 25° C. Grams per 100 cc.	Median lethal dosage range Mg. per gram
Fluorides:			
Sodium	NaF	4.054	0.11–0.15
Manganese	MnF_2	.186	.20– .40
Lead	PbF_2	.066	.25– .40
Magnesium	MgF_2	.013	>.57
Fluosilicates:			
Sodium	Na_2SiF_6	.762	.10– .13
Potassium	K_2SiF_6	.177	.07– .10
Barium	$BaSiF_6$	.025	.09– .12
Fluoaluminates:			
Sodium	Na_3AlF_6	.061	.05– .07
Potassium	K_3AlF_6	.158	.08– .10
Ammonium	$(NH_4)_3AlF_6$	1.031	.11– .14

[1]For comparative purposes it may be helpful to state here that the median lethal dose of acid lead arsenate is about 0.09 mg. per gm.

The solubility of the fluorine compounds in water was not directly related to toxicity except among the four fluorides. In the first paper mentioned above, Campbell and Filmer published median lethal doses for commercial samples of potassium fluosilicate, barium fluosilicate, and sodium fluoaluminate. The higher degree of purity of the present samples may account partly for their greater toxicity for the silkworm. The present senior author also tested the fluoaluminates of strontium, zinc, barium, magnesim, and calcium. They were less toxic than the fluoaluminates listed in Table 1. Their toxicity decreased in the order named. The results with these compounds are not given in Table 1 because they were of indefinite composition and their solubilities were not determined.

H. H. SHEPARD, *Bureau of Entomology*, and R. H. CARTER, *Bureau of Chemistry and Soils, U. S. Department of Agriculture*

The Effects of Various Commercial Calcium Arsenates on Bean Foliage. Owing to the increased interest in the use of calcium arsenate as a substitute for lead arsenate in order to avoid the problem of lead residue on edible portions of fruits and vegetables, results of three seasons' investigations on the effects of calcium arsenates on bean foliage have been summarized. Since facilities for publishing this report are not available, owing to its length and scope, it has been multigraphed by the Bureau of Entomology.

The report deals with the effects of 19 commercial calcium arsenates on the foliage of green beans in Ohio during 1929, 1930, and 1931. It shows that 5 of the brands were arbitrarily rated as safe, 5 brands were rated intermediate, and 9 brands were rated as unsafe, for use on bean foliage.

The following conclusions were drawn:

Previous experience has indicated—and the conclusions are substantiated in this investigation—that hydrated lime is the most practical corrective for use with commercial calcium arsenate on bean foliage. A combination of sulphur and hydrated lime is an efficient corrective in the proportions of 1–1–4 by weight (calcium arsenate, sulphur, and hydrated lime, respectively).

Bordeaux mixture is an excellent corrective and is more effective than lime, but may itself cause plant injury under certain conditions if used alone.

Copper-lime dusts are good correctives but may cause foliage injury as in the case of Bordeaux mixture if used alone.

The rate of evaporation in the air as measured by atmometer spheres appears to be an important index of atmospheric conditions which influence the degree of foliage injury caused by the application of calcium arsenate to bean foliage. Quick drying of the spray tends to mitigate foliage injury.

It is difficult if not impossible in many instances to correlate the effects of humidity and temperature with the degree of foliage injury.

Water-soluble arsenic, as present in most of the brands tested, is not an important index of foliage injury.

No methods of determining by chemical analysis why some brands "burn" and others do not could be devised by careful investigations carried on cooperatively by chemists.

The uniformity of the gross chemical composition and of the toxicity to larvae and adults of the Mexican bean beetle tends to show that from certain standpoints commercial calcium arsenates are well standardized products. On the other hand, the variability of the effects of different brands as regards toxicity to bean foliage is very great.

A few copies of the report are available for investigators who are interested, and may be obtained from the Bureau of Entomology, Washington, D. C., or from the authors at the following addresses: Neale F. Howard, 151 W. 11th Ave., Columbus, Ohio; F. W. Fletcher, State College of Forestry, Syracuse, N. Y.

NEALE F. HOWARD and F. W. FLETCHER, *U. S. Bureau of Entomology*

A Note on the Insecticidal Efficiency of Kerosene Extracts of Derris Alone and in Combination with Kerosene Extracts of Pyrethrum. In connection with some investigations on household sprays of the kerosene base type, extracts of

derris powder were prepared by percolation and tested in comparison with kerosene against house flies according to a method previously described.[1] Derris extracts were also added to pyrethrum extracts to ascertain if they would increase the final toxicity of such sprays.

The kerosene used was of midcontinent origin—41°A.P.I. distillation range 378°F. (192°C.) to 516°F. (269°C.) with 50% over at 454°F. (234°C.). *The derris powder* was finely ground (about 200 mesh) and was found to contain approximately 2.9% rotenone on analysis by the method described by Roark.[2] *Kerosene extracts* of this powder were prepared by first macerating the powder for several hours with kerosene in a glass percolator and then allowing percolation to proceed slowly. Extracts were prepared on the basis of 23.8 gms. of powder to 100 cc. of kerosene (approximately 2 pounds to 1 gallon.). *Pyrethrum extracts* were prepared by the same method in the proportion of 11.9 gms. of pyrethrum powder (0.26% pyrethrin 1) to 100 cc. of kerosene (approximately 1 pound to 1 gallon.). The *combination of derris extract* with *pyrethrin extract* was prepared by adding 16.6 cc. of the derris extract prepared as above to 83.3 cc. of the pyrethrum extract. This was tested in comparison with another sample of the same pyrethrum extract which was diluted with 16.6 cc. of kerosene to 83.3 cc. of the extract.

The results of the insecticidal tests are shown in the table:

Series	Test solution	No. of tests	No. of flies	Average 50 per cent paralytic time in seconds	Mortality after 24 hours per cent
1	Kerosene	2	94	405	18
	Kerosene extract of derris	2	110	332	68
2	Extract of pyrethrum	4	197	197	46
	Extract of pyrethrum plus derris extract	4	198	190	59

It was clear that kerosene extracts of derris are much more toxic than kerosene alone. Furthermore it appeared that the addition of small amounts of derris extract to pyrethrum extract gives a significant increase in toxicity. Whether the toxicity of the kerosene extract of derris is due to rotenone is a question. Certainly rotenone was present. Jones and Smith[3] report that the solubility of rotenone in kerosene is less than one-tenth of 1% at 20°C. Possibly extractives of derris other than rotenone contributes to the toxicity of the kerosene extract. It is apparent that derris contains some kerosene soluble compounds which add considerably to the toxicity of the kerosene toward house flies.

It might be of interest to mention that kerosene extract of Quassia chips and hellebore (both at the rate of 11.9 gms. per 100 cc.) were tested but they did not appear to add very significantly to the toxicity of kerosene.

This work was part of a Crop Protection Institute Fellowship supported by the Deep Rock Oil Corporation. The author is now with the U. S. Bureau of Entomology, Washington, D. C.

HENRY H. RICHARDSON, *Iowa State College, Ames, Iowa*

[1]Richardson, H. H. Jour. Econ. Ent. 24 (1): 97–105. (1931).
[2]Roark, R. C. Soap 7, No. 3, 97–101. (1931).
[3]Jour. Am. Chem. Soc. 52, 2445–52. (1930).

The Occurrence of *Bregmatothrips iridis* Watson in the United States. While investigating the gladiolus thrips, *Taeniothrips gladioli* M. & S., the author on October 26, 1931, collected a few dark brown wingless adult thrips in the leaf axils of the common torchlily, *Kniphofia uvaria*, and a large number on Japanese iris plants at a nursery in Hamburg, N. Y., which were identified by Harold Morrison, U. S. Bureau of Entomology as *Bregmatothrips iridis* Watson. This collection apparently represents the first record of the insect's establishment in the United States. Although this thrips has been intercepted a number of times since 1923 (Watson, J. R. Entomologists' Monthly Magazine 60: 253–254, 1924) on iris imported from Holland, England, and France, it has not been reported as having become established in America.

During the past season other infestations of this thrips on iris have been found by members of the Bureau of Plant Quarantine, or on material which was sent to the Bureau of Entomology, from several places in New York and one in Maryland. An interception in 1932 by Norman Perrine on imported bulbous iris of a single winged thrips was identified as this species by Professor Watson, who commented on the importance of the fact that this thrips sometimes produces winged individuals, its ability to become disseminated being thereby increased.

Although the thrips has been found most frequently on various types of iris, it has been taken on the common torchlily and so it may not be restricted in its host range. The insect may be rather widespread in the United States on iris plantings because these plants have been imported for many years prior to the first discovery of the insect.

The iris plants at Hamburg were again examined on April 18, 1932, and only adult females were present upon the young shoots beneath the sheaths of dead leaves of the plants. No young were present and, since egg laying started soon after the females were placed in a warm temperature, it is evident that the winter is passed as fertilized females. The infestation was again examined in August, 1932, and the thrips were found only on the iris. The thrips, including the milky white larvae and pupae, and the dark colored, wingless males and females, were abundant in the leaf axils.

The foliage of infested plants was rather severely stunted. The areas of leaf tissue which had been fed upon while in the sheaths and then grew out by leaf elongation appeared brownish or rusty colored. The few late flowers were not injured and the grower stated that he observed no flower injury during the whole season. The discolored and stunted foliage was noted by recent correspondents desiring information on the cause of the injury to their plants.

With reference to control it appears that rather drastic measures would be required to clean up infested plants because of the secluded situations in which the insect occurs. Spraying or dusting would appear to offer temporary relief rather than elimination. The latter may be possible by digging the plants in the late summer, when they are usually dug for division and replanting, and immersing them in hot water for from 15 to 20 minutes at a temperature of 120°F.—a treatment which has been provisionally adopted for imported iris by the Bureau of Plant Quarantine pending adequate research on the control of this species.

FLOYD F. SMITH, *Division of Truck Crop and Garden Insects,*
U. S. Bureau of Entomology

The Influence of Insects in the Souring of Figs. In the summer of 1928 while engaged in investigations on figs in connection with the operation of the Federal food and drug act, a series of experiments was made to throw light on the possible influence of insects in the souring of figs. This souring in figs is caused by various yeasts and bacteria and it was felt that insects entering the figs probably acted as carriers of the microorganisms. For the experiment, a certain tree in a fig orchard a few miles southeast of Fresno, Calif., was generously set aside for our use by the owner. The plan was to prevent insects from entering a portion of the figs on the tree and to compare these after maturing and drying with other figs from the same tree which had not been thus protected.

At the outset, three methods of protection suggested themselves. These were: (a) to smear over the ostiole or "eye" of the fig a layer of automobile grease, (b) to use "tree tanglefoot" for this purpose, and (c) to enclose the figs in small cloth bags. After the first test it was found that the automobile grease killed the tissues it came in contact with and hence invited decay. Therefore, its further use was abandoned. The tanglefoot did not seem to affect the tissues adversely.

Each set after preparation was allowed to remain on the tree until the figs ripened and dropped on the ground in the usual fashion. Three successive sets were started about a week apart between August 18 and early September. At each time of visit to the orchard those figs that had dropped since the last visit were collected and tested.

In choosing the figs for the experiment, note was made of the stage of development as indicated by the condition of the scales around the "eye", since as the figs approach maturity the scales draw apart, making the entrance of the insects an increasingly easier matter. In "stage 1" were classed those figs in which the scales appeared closely interlocking, while in "stage 2" were classed those figs wherein the scales were beginning to open appreciably. Observations of many individual figs previous and subsequent to this experiment, revealed the fact that the dried fruit beetle and the vinegar fly sometimes crowd their way into figs that would at first be regarded as too tightly closed. This may help to explain the small number of sours that were found on testing the figs in the "stage 1" series.

Samples of the naturally handled, unprotected fruit from the same tree were gathered periodically and tested according to the methods used for figs in the Federal Food and Drug Adminstration (1). During the experiment six sets were collected and tests gave the following average:

Insect infested	37.2%
Moldy	2.0
Sour	16.0
Bird-pecked and dirty	3.4
Passable	41.4

According to the technique of the method of testing, the above figures fail to reflect perfectly the full extent of souring, since no fig is counted in more than one class, and if it is insect-infested as well as sour, it is classed only as the former. As a matter of fact, a very large proportion of those classed as insect-infested were also sour.

Examination of the protected figs showed the following:

	State of development			
	Stage 1 Scales closed		Stage 2 Scales opening	
	No.	Per cent	No.	Per cent
Figs with sour odor	2	2.1	3	10.0
Figs with traces of yeasts or bacteria	4	4.2	3	10.0
Figs with no evidence of souring	89	93.7	24	80.0

There was no significant difference in souring between those protected by the cloth bag and those treated with tanglefoot.

A comparison of the results obtained in the unprotected series with those obtained in the protected series, especially those of "stage 1," reveals a very marked difference in that in the latter group only about 2 per cent showed souring to such a degree as to be organoleptically detected.

Although the extent of the experiment was too limited to warrant drawing final conclusions, the results obtained certainly appear sigificant.

In conclusion the writer wishes to acknowledge the cooperation of members of the Stored Products Insect Investigation Laboratory of the United States Bureau of Entomology, located at Fresno, Calif., in conducting the experiment.

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United State Department of Agriculture

JOURNAL OF ECONOMIC ENTOMOLOGY

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JUNE, 1933

The editors will thankfully receive news matter and other items likely to be of interest to our readers. Papers will be published as far as possible in the order of reception, except that papers of reasonable length may be accepted in the discretion of the editor for early publication at $3.00 per page. There is a charge of $3.00 per page for all matter in excess of six printed pages, a part page counting as a full page, this limit not including acceptable illustrations. Photo-engravings may be obtained by authors at cost.

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A. A. A. S. Winter meetings: 1933-34 Boston; 1934-35 Pittsburgh; Summer meetings: 1933 Chicago. 1934 San Francisco.

Economic or applied entomology deals primarily with insect control. This work is playing an increasingly important part in the economic life not only of this Nation but in all countries throughout the world. The National and international character of this activity is strikingly evident in a recent book entitled: "Fighting the Insects, The Story of an Entomologist." It is really an autobiography of one who held for many years with great credit the entomological leadership of the world. The story of his early years agrees in large measure with similar accounts of other noted men of science. Entomologists will find in this volume inspiration, since it details briefly and interestingly many of the numerous contacts the author was able to establish with leaders in scientific thought, both in this country and abroad. It records a gradual and healthy increase in a general realization of the importance of economic entomology and the acceptance of the entomologist as an equal by leading students in other branches of learning. The book calls attention, by implication at least, to the importance of numerous personal contacts with investigators in other sciences and with men of affairs, both valuable agents in molding public opinion. This is the story of a man who visualized clearly the human relations of his science and by virtue of his position and connections was able to bring it most effectively to the attention of the entire world. The title: "Fighting the Insects" though usually interpreted to mean something very different, namely, actual

work in the field, is entirely justified by the contents of the work, since it deals with a very important phase of insect control. The book contains much of human interest in relation to a man who has enjoyed exceptional opportunities in his chosen work. There were tremendous advances made during his period of active service. There are possibly even greater advances to be made in the not distant future. The volume illustrates in a striking way the value of well directed, intense research or specialization, and at the same time, emphasizes the importance of the broader outlook which reaches beyond State and National boundaries. There is need of more such men.

Obituary

CLARENCE RITCHIE PHIPPS

1895—1933

CLARENCE RITCHIE PHIPPS died Wednesday morning, June twenty-first. He had been occupied with his entomological work all day Monday (June nineteenth) apparently in his usual health but he became acutely ill that night. Tuesday an operation was deemed imperative and his wife, who was visiting her parents in Syracuse, New York, was informed of his serious condition. Mrs. Phipps arrived by chartered airplane, and in appreciation of her haste her husband's smiling welcome was, "Esther, you made good time." His sudden exit from the various activities in which he had so keen an interest took place a few hours later. He is survived by his wife, Esther Sears Phipps, his son Richard, and his mother, Mrs. Phipps of Quincy, Massachusetts.

In preparation for his professional work, he received his degree of B.S. from the Massachusetts Agricultural College in 1919, M.S. from Iowa State College in 1927, and Ph.D. from Cornell University in 1930. From 1919–21 he served as Assistant Entomologist at the New York Experiment Station, Geneva, New York. From 1922–25 he held the position of Entomologist at the State Fruit Experiment Station, Missouri. Since July 1925 he has been in charge of the Purnell Projects in the Department of Entomology at the Maine Agricultural Experiment Station. At all three institutions with which he was connected, he was engaged in economic work with fruit insects.

Fruit growers in Maine who placed their insect problem before Doctor Phipps realized his earnest efforts in their behalf and repeatedly ex-

Plate 41

Clarence Ritchie Phipps

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pressed their appreciation of his help. His recent publications on blueberry insects and the apple fruit fly have been received with praise by his entomological colleagues.

Those associated with him in his professional work found Doctor Phipps patiently persistent in his endeavors, conservative in his judgment, pleasant in his personal contacts, ready to accept pertinent advice, generous in his evaluation of the work of others, earnestly and progressively ambitious to improve the caliber of his research in each new undertaking. He had unusual ability in the organization of essential details in planning his projects and in recording the results of his observations. To quote from the June 28, 1933, issue of *The Station News*, of Geneva, New York: "That he would attain still further heights in his chosen field of work was the expectation of all who knew him."

Doctor Phipps, by nature quiet, sincere, gracious, had won the respect and affection of a wide circle of friends. One of these, Mr. Arthur Stevens, says of him:

"The loss to Entomology in the passing of Doctor Phipps is not greater than the loss to the community in which he made his home. Outside of his work his first thought was to his family. As a husband he had the two greatest contributions to happiness—sympathy and understanding. His intelligent devotion to his son was a type that inspires and encourages useful citizens for the next generation.

"Doctor Phipps had a variety of hobbies and interests. Perhaps the foremost of these was Contract Bridge. He was an excellent player and a sporting loser. Baseball claimed some of his enthusiasm, especially the fortunes of the Boston Braves. He was more than casually interested in all outdoor sports and handled most of them in a capable manner. His tennis was better than the average. He was an ardent fisherman. He had recently joined the Penobscott Valley Country Club and was looking forward to improving his golf.

"Perhaps the greatest asset in Doctor Phipps' character was his consideration for other people. He was unfailingly thoughtful of the comfort of others, even to his own discomfort. His pleasure seemed to be the pleasure of others and his will the convenience of his associates. His sudden passing came as a shock to his friends who will hold in memory a realization of so true a man and a sadness in the loss of so fine a friend."

EDITH M. PATCH.

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Current Notes

The pale western cutworm situation in Alberta, Canada, is somewhat more serious than was expected, owing to peculiar weather conditions of the season.

Mr. A. G. Dustan and other members of the Entomological branch at Ottawa have noted with interest that there is no evidence indicating that the gladiolus thrips winters outside in that latitude.

Glenn M. Kohls and Carl L. Larson, Assisant Entomologists, returned to the Laboratory at Hamilton, Montana, after two months in the field on a tick survey through several of the states of the southwest and Pacific Coast.

The white grub outbreak expected in eastern Ontario, Canada, is proving to be even worse than anticipated. Extensive damage is being caused on a very large acreage entailing a threatened shortage of winter fodder on many farms.

Mr. Arthur Kellsall, Entomological branch, reports that insectary feeding tests being carried on by Mr. S. H. Payne are showing that the new process white arsenic, used alone or combined with fungicides, is considerably more toxic per unit of arsenic than lead arsenate.

The grasshopper outbreaks in Manitoba and Saskatchewan proved to be extremely destructive and in the former locality was one of the worst known in the history of the province. The areas of outbreak conformed excellently to the forecast map issued in the early season.

Mr. W. A. Ross, Entomological branch, reports that a 20 per cent lubricating oil spray applied to pear trees for the eighth consecutive year caused no serious injury apart from the usual marked retardation in the development of leaf buds. The trees sprayed with 10 per cent appear to be normal.

The gladiolus thrips, *Taeniothrips gladioli* M. & S., was first found infesting gladiolus in South Carolina at Clemson College on June 3rd, 1933. The specimens were found on plants which grew from infested corms which were imported from Rose Hill, N. Y. in November, 1932. The corms were fumigated before being planted, but the treatment was evidently insufficient to kill all individuals present.

Among interceptions of diseased nursery stock in Canada, one of *Taeniothrips gladioli* is of special interest. This insect was found in a shipment of 125 gladioli bulbs from Australia. The insect was identified by M. B. Steinweden of San Francisco. In June another shipment of gladiolus consigned to Winnipeg from New Zealand was found infested with thrips, but the species has not yet been determined.

The Pan Pacific Science Congress was held at Vancouver, B. C., June 5–14. Entomologists present from outside of Canada included Dr. Tillyard of Australia; Dr. Swezey from Honolulu; Dr. Harry Smith from California; Dr. Parker and Dr. Cooley from Montana; Dr. Mote from Oregon and Dr. Kincaid from Washington University. The Canadian members included many of the officers of the Branch in British Columbia, three from Ottawa and several from the University of British Columbia.

Mr. Norman Criddle, entomological branch, died at Brandon, Manitoba, May 4th. He died as the result of an operation late in April which was necessary be-

cause of poor health during recent years. He had been in charge of the Treesbank laboratory for a period of nineteen years and was a well known worker in the field of entomology. On March 31st, the Manitoba Agricultural College granted him an honorary diploma, the highest honor in their power to bestow, in recognition of his accomplishments on behalf of agriculture.

During the 20th annual meeting of the New Jersey Mosquito Extermination Association held at Atlantic City, N. J., April 20 and 21, it was reported that since the year 1900, there has been spent in New Jersey over six million dollars for mosquito control. The assessment value of property in the state during the same period rose from 64 million dollars to 736 million dollars in 1930. Much of this property is situated in sea-shore locations, and previous to mosquito control, was comparatively useless.

Members of the Rocky Mountain spotted fever Laboratory, Hamilton, Montana, who attended the Vancouver meetings of the Fifth Pan Pacific Science Congress, were Dr. R. R. Parker, Officer in Charge, and Mr. R. A. Cooley. Dr. Parker read a paper regarding recent advances in the study of tick-borne diseases in the western United States and Professor Cooley summarized present information on tick parasites and attempts to colonize *Ixodiphagus caucureti* in certain localities in the West. In honor of his long service to economic entomology, Professor Cooley was inducted for the day as temporary chairman of the biological section.

The last meeting of the Entomological Club of Southern California for the year 1932–1933 was held on June 2, at the University of California at Los Angeles, with an attendance of 91 members. The following newly-elected officers were installed: President, A. F. Swain, Pacific R. & H. Chemical Corporation, El Monte; Vice-President, S. E. Flanders, University of California Citrus Experiment Station, Riverside; Secretary and Treasurer, H. C. Lewis, California Fruit Growers' Exchange, Los Angeles. The retiring officers were: President, C. I. Bliss, U. S. Bureau of Entomology, Whittier; D. W. Tubbs, Agricultural Commissioner of Orange County, Santa Ana; Secretary and Treasurer, A. M. Boyce, University of California Citrus Experiment Station, Riverside.

Joint Meetings of Section F. with Affiliated Entomological Societies and Joint Meeting of American Association of Economic Entomologists and Entomological Society of America at Chicago, Ill., June 22, 23, 1933. A joint meeting of Section F. of A. A. A. S. with the affiliated entomological societies was convened at the James Simpson Theater, Field Museum, on June 22 at 10 A. M., with about 150 in attendance. The president of the American Association of Economic Entomologists, Dr. W. E. Hinds, presided during the opening address which was given by Dr. R. J. Tillyard of Canberra, Australia. Dr. Tillyard presented an interesting and well illustrated discussion of various theories of "The Evolution of Insects," closing with a statement of his own conclusions which have been based upon long study in this field.

Dr. A. J. Carlson presided during the second address of the joint meeting which was given by Dr. A. V. Hill, of University College, London. Dr. Hill spoke upon "Wave Transmission as the basis of nerve activity."

Entomologists Dinner at Chicago. At the joint banquet of the two entomological societies held in Chicago the evening of June 23, Dr. C. H. Richardson, Vice-

President of the Entomological Society of America acted as toastmaster. After opening the gathering, the meeting was turned over to President W. E. Hinds of the American Association of Economic Entomologists. He presented to Past President Flint a diploma to acknowledge his effective leadership of the Association during the past year. Very interesting talks were given by Dr. E. F. Phillips on "Entomology in Soviet Russia—with particular reference to Beekeeping," and by Mrs. Phillips on "Certain Aspects of Home Economics in the Land of the Soviets."

President Hinds then announced that on May 14 he had appointed a special committee, consisting of Messrs. Britton, Cory, Felt, Houser and Phillips (chairman), to do whatever was possible to preserve the integrity of the entomological investigations and services of the federal government and of the state investigations supported by federal funds. A preliminary report of this committee was then read by the chairman in which the work of the committee to date was briefly outlined. The committee met in Washington May 19 and remained there for three days, during which time a considerable number of interviews were held. Since at that time definite annoucements had not been made regarding the proposed reorganization of the federal services or regarding the proposed reductions, the committee confined its efforts to the making of certain specific recommendations which it hoped might be followed in the changes which are ahead. Insistence was placed on the importance of retaining the entomological research as a single administrative unit, since it has been proposed to split the work among a number of distinct bureaus. It was also urged that the foreign quarantine be retained with as little reduction as possible, and that funds for state investigations be continued, since many of them are long time projects, for which much valuable data would be lost if they were suddenly curtailed.

Following the reading of this report, the meeting was turned back to Vice-President Richardson, after which it was moved and duly passed that the same committee be authorized hereafter to act also on behalf of the Entomological Society of America, the expenses to be met jointly by the two organizations.

Horticultural Inspection Notes

A conference to consider the suppression and prevention of spread of the potato wart disease is scheduled to be held at Hazelton, Pa., on July 28.

Under BPQ-352, the Federal Bureau of Plant Quarantine has issued a definition of the term "commercially-packed shipments of apples," as used in the Japanese beetle quarantine regulations.

According to the Florists' Review, Phil S. Haner, of Taylorville, Ill., superintendent of the division of plant industry of the Illinois state department of agriculture and an honorary member of the Illinois State Nurserymen's Association, died July 17 at Springfield, Ill., following an operation.

J. D. Winter who was in the nursery inspection service of the state department of agriculture, severed his connection with that work July 1. Mr. Winter, according to the Florists' Review, is now Secretary-treasurer of a new organization, the

Minnesota Fruit Growers' Association. Growers from all over the state are eligible for membership.

Mr. Ralph M. Seeley, formerly connected with the gipsy moth project of the Bureau of Entomology, United States Department of Agriculture, has been appointed horticultural inspector in the New York State Department of Agriculture and Markets, with headquarters at Binghamton.

The Office of State Entomologist of Wyoming has now been moved to Powell. It continues as a branch of the State Department of Agriculture with headquarters at Cheyenne, but letters for the attention of Mr. C. L. Corkins, State Entomologist, should be addressed to Powell to receive prompt attention.

Certain varieties of Castanea are now admissible into Illinois under certain safeguards and "in cases where it is desirable to import [them] because of their resistance to the Chestnut bark disease and superior quality of the fruit produced." The proclamation is dated April 29, 1933, and modifies the embargo formerly in effect.

The alfalfa weevil quarantine of the State of Michigan was revised on May 4 as a result of surveys made and data collected "which show that infestation exists in five new counties in California and two new counties in Nevada.". The newly quarantined counties are Alameda, Contra Costa, Mono, San Joaquin, Santa Clara, and Stanislaus in California, and Eureka and Landers in Nevada.

New reports on the Dutch elm disease by the Federal Bureau of Plant Industry show that the disease has been discovered on at least nine American elm trees at Maplewood, South Orange and East Orange, N. J. One additional infected elm has also been located at Cleveland, Ohio. No nursery has been found infected nor has any connection yet been established between the various diseased trees and any nursery.

Under a recent reorganization of the State Department of Agriculture of Michigan, Samuel T. Metzger was named Commissioner of Agriculture, and C. D. Doane, Chief Apiary Inspector. Mr. E. C. Mandenberg continues in charge of nursery and orchard inspection. Inspectors working under his direction include C. A. Boyer, A. H. Beyer, H. Kiebler, L. Small, H. Tichnor, J. Garver, W. N. Banfield, H. N. Blackmer, Sidney Davis, Clifford Rowe, Francis Meiers, Robert Audrain, and Kenneth Clark.

Recent revisions of the Wisconsin and Missouri regulations relating to the European corn borer remove from the list of restricted articles celery, oat and rye straw, cosmos, zinnia, and hollyhock; place no restrictions on floral plants and vegetables entering from Michigan, Ohio, and Indiana; and provide for the acceptance without restriction of green corn during a portion of the year and of chrysanthemums, asters, and dahlias without old stems during four months of the year. The Wisconsin order became effective on June 16 and the Missouri order on July 10.

Mr. L. M. Gates, Nursery and Apiary Inspector of the Nebraska State Department of Agriculture, reports that the last legislature reduced to $10,000 an appropriation which had previously amounted to $25,000 per biennium for the control

of the European corn borer or other highly dangerous insect pests. This fund has heretofore been employed primarily for grasshopper control and it is stated that $7,000 of the biennial appropriation has already been spent for grasshopper poison bait this season. The outbreak is so severe that according to Mr. Gates much more is needed.

Based upon assurance from the Oregon officials that no cherry fruit fly infestation is to be found in the counties of Union, Baker, and Wallowa in that State, the California State Department of Agriculture on June 8, modified its quarantine relating to these pests by eliminating these counties from the areas under regulation. The modification is designated "Quarantine Proclamation No. 8," the first "Proclamation," according to the Department which it has issued. The term "Quarantine Proclamation," is to be used when areas in other States are involved, but "Quarantine Regulations" when areas in California are involved.

Shipping restrictions with reference to the phony peach disease have been passed recently by the States of Mississippi, Arkansas, and Delaware, which include the following requirements as a condition of entry of the susceptible plants: (1) Disease-free plantings and disease-free environs within a mile thereof; (2) borer-free stock as determined by hand inspection after digging. In the case of Delaware, stock which meets either condition (1) or (2) is acceptable. As a further condition of certification, the State of Mississippi also requires that the stock be produced in a disease-free county.

Supplementary administrative instructions relating to narcissus treatment and pest suppresson have been issued by the Federal Bureau of Plant Quarantine as circular BPQ-353. The new circular authorizes the use of the vapor heat treatment for bulb flies in lieu of the hot water treatment, if desired. It also changes the presoaking requirement by reducing the length of time dry bulbs are required to remain in cold water from 12 hours to 2 hours. A number of interpretations and slight modifications of the administrative instructions concerning narcissus inspection issued last year are included.

The Ohio State Department of Agriculture recently issued a regulation relating to the two-generation strain of the European corn borer. The order, which became effective on July 7 applies only to the New England States, New York, New Jersey, Pennsylvania, and Virginia, and provides for acceptance of the restricted articles when manufactured or processed, and of floral and vegetable plants and products when certified. It places no restrictions at any time of the year on celery, oat and rye straw, dahlia tubers or gladiolus corms without stems, or cosmos, zinnia, or hollyhock. From January 1 to June 1 each year, green corn, chrysanthemums, asters, dahlias, and cut gladiolus without old stems, may be admitted without restriction.

Active steps are being taken by the Bureau of Plant Industry of the New York State Department of Agriculture and Markets to bring under control an infestation of the European pine shoot moth in the nurseries of southeastern New York State. For this purpose a control measure worked out by Dr. R. D. Glasgow, State Entomologist, is being employed. The method consists of spraying with any one of a number of formulae. It is stated in the circular of instructions issued by Doctor Glasgow and Mr. B. D. Van Buren that the most successful of these formulae

consists of 1½ pints of Cube extract (containing 5% Rotenone oil), and 2 gallons of miscible pine oil in 100 gallons of water. The nurserymen are instructed to spray thoroughly between June 25 and July 4, directing the spray branch by branch, downward and inward, so that it may penetrate the needle clusters from the tip toward the base. Two applications, one near the beginning and one near the end of the period named, are advised. It is stated that this treatment has given good results even in severe infestations.

Mr. L. A. Strong, Chief of the Bureau of Plant Quarantine, United States Department of Agriculture, addressed the American Association of Nurserymen at Chicago on July 20, on the subject "The Past, Present and Future of Quarantine 37." Mr. Strong forecast serious consideration of the modification and liberalization of Plant Quarantine No. 37. Among the fundamentals which he stated should be continued were restrictions on the introduction of soil, a limitation on the age and size of plants to keep them within the Department's ability to make competent inspection, and the continued exclusion of classes of plants that are likely to bring in injurious pests from specific localities. It was stated that greater confidence can now be placed in the efficacy of inspection of plant material at the time of arrival than was possible some years ago. Mr. Strong pointed out the objections to the Federal Department attempting to limit the number of plants to be imported on the basis of the availability of the varieties concerned and stated that he questioned the need for any requirement that imported plants be kept in detention for any certain period of time.

The fifteenth annual conference of the Western Plant Quarantine Board was held at Salt Lake City, Utah, June 12 to 14, 1933. In addition to representatives of many of the western States, there were present Mr. William C. Wood, Chief of the Division of Classification of the United States Post Office Department; Sr. E. Coppel Rivas, of the Agricultural Defense Office of the Republic of Mexico; and Mr. W. H. Lyne of British Columbia. The Board passed resolutions relating to the recognition of State plant quarantines by the Post Office Department; recognition and acceptance of Federal origin inspection and certification as a basis for admitting commodities which might otherwise be embargoed under State plant quarantines; the method of enforcement of the Lacey Act relating to the entry of injurious mammals and birds from foreign countries, and the importance of preventing the interstate shipment of weed seeds. The Board discussed but took no action with respect to the certification of honey in interstate commerce; the spread of the black walnut canker disease; the elimination of the European earwig in the soil about the roots of balled nursery stock; the Colorado potato beetle situation; the outbreak of the strawberry-iris worm; the problem of cooperative border stations; protection against the spread of the potato tuber moth, and the maintenance of identity of fruit and vegetable shipments by means of sealing the containers. The Republic of Mexico was elected to full membership in the Board. W. H. Wicks of Idaho was elected Chairman for the ensuing year; D. C. George of Arizona, Vice-Chairman, and A. C. Fleury of California, Secretary-Treasurer. George M. List of Colorado was elected as representative to the National Plant Board, to serve with A. C. Fleury whose term had not yet expired.